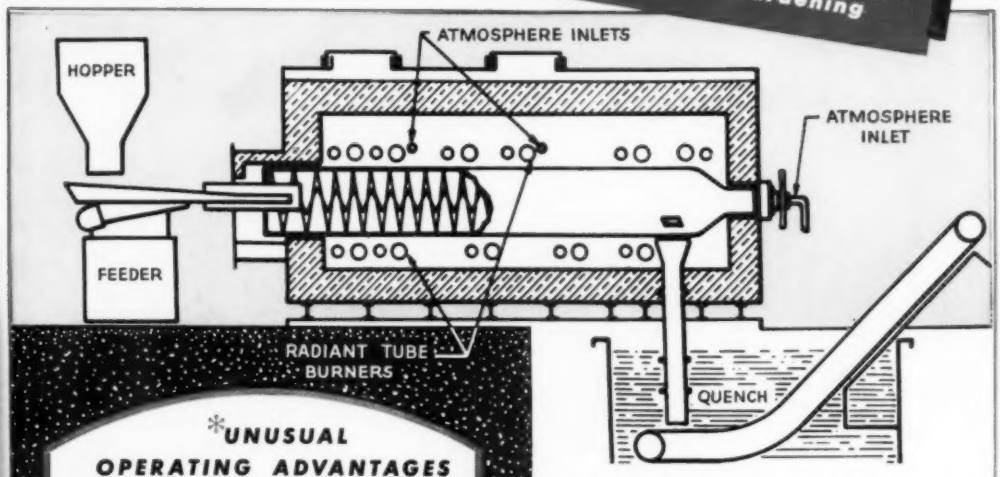
METAL PROGRESS

Fully Automatic—High Production

ROTARY RETORT
CONTROLLED ATMOSPHERE FURNACES*

FOR MODERN HEAT TREATMENT INCLUDING:
Gas Carburizing
Dry (gas) Cyaniding
Homogeneous Carburization
and Clean Hardening



*A 'Surface' Rotary Retort Furnace is equipped with one or more cast alloy retorts, each provided with an internal screw thread. The retorts are operated with an oscillating type of motion which is gentle and non-abrasive and accomplishes a forward movement of the metal pieces through the retort.

*UNUSUAL OPERATING ADVANTAGES

1. Improved and uniform contact of metal pieces with the prepared gas atmosphere, as compared with other types of work handling.
2. High thermal efficiency. No trays or fixtures to heat or cool.
3. Fully automatic operation possible . . . minimun of manual handling. Low maintenance costs.
4. Especially adaptable to limited production by control of rotation cycle and/or charging rate.
5. 'Surface' RX Gas Atmosphere Generator supplies atmosphere gas for all modern heat treatments.

● 'Surface' Rotary Retort Furnaces are the first successful units of their kind because a protective atmosphere is utilized within the heating chamber as well as the rotary retort. A positive pressure is maintained within both areas, thereby protecting the metal from outside air contamination during heat treating and quenching.

These units provide unusually high quality heat treatment. Capital investment about 40% that of equivalent pusher-type furnace. Minimum space required for high production.

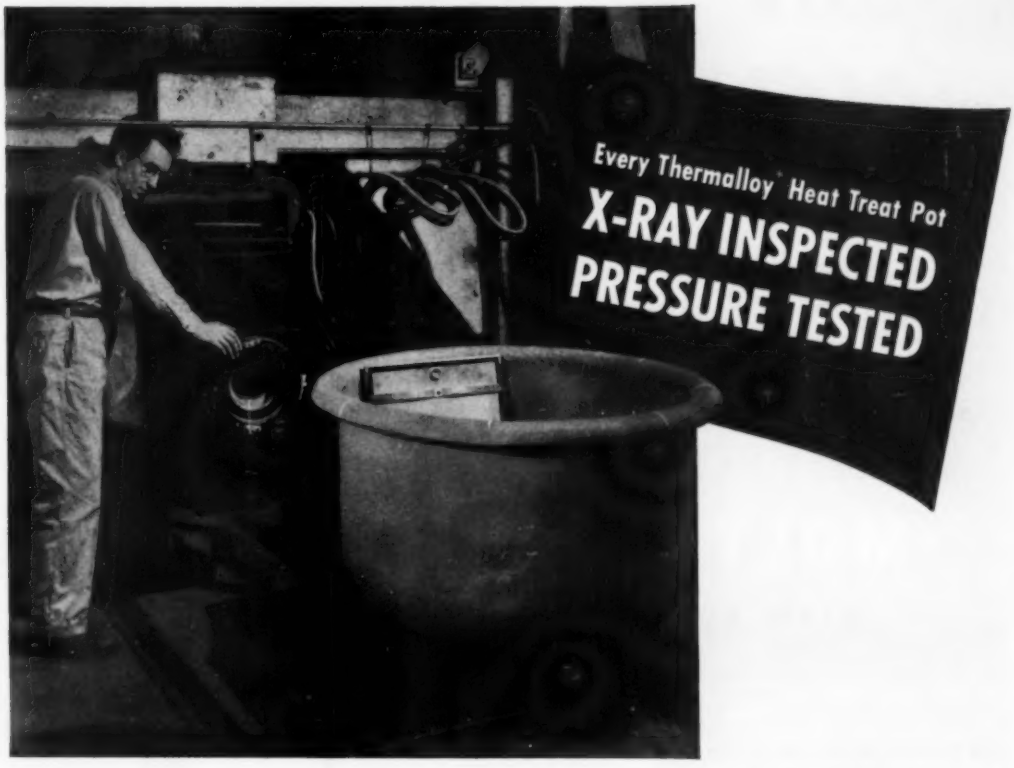
◀ *Complete details are given in Bulletin SC-147. Write for your copy today!*

SURFACE COMBUSTION CORPORATION • TOLEDO 1, OHIO

FOREIGN AFFILIATES:
Stein & Roubaix, Paris — *British Furnaces, Ltd., Chesterfield*

'Surface' **INDUSTRIAL FURNACES**

FOR: Gas Carburizing and Carbon Restoration (Skin Recovery), Homogeneous Carburization, Clean and Bright Atmosphere Hardening, Bright Gas-Normalizing and Annealing, Dry (Gas) Cyaniding, Bright Super-Fast Gas Quenching, Atmosphere Malleableizing and Atmosphere Forging. Gas Atmosphere Generators.



HERE'S PROOF OF QUALITY!

- Life of Electro-Alloys neutral salt pot proved to be eight times that of competitive type pot formerly used. User saved over $100 on initial cost alone during life of one pot—plus replacement labor costs of seven pot changes.

- With a competitive alloy, customer was receiving 1,500 to 3,500 hours service. On switching to Thermalloy pots, service life jumped to 3,800-5,550 hours in identical service.

Another reason why you get
More Operating Hours per Dollar

To insure the soundness necessary for low-cost service, every Thermalloy Heat Treat Pot is subjected to thorough internal and external inspection. Two X-ray machines, operated by trained radiographers, reveal any hidden flaws or weaknesses which might shorten service life. Pots are also pressure-tested at 60 pounds per square inch. This eliminates the possibility of porosity that does not show up on X-rays.

This careful inspection, plus Thermalloy's outstanding heat-resistant properties, are your guarantee of top quality. Why not make Thermalloy your standard in buying heat treat pots?

Over 100 sizes in both round and rectangular pots are available for production from stock patterns. Write for Bulletin T-205, listing shapes and sizes available. Electro-Alloys Division, 2096 Taylor St., Elyria, Ohio.

Specify THERMALLOY* for heat and abrasion resistance... CHEMALLOY* for corrosion resistance

*Reg. U. S. Pat. Off.

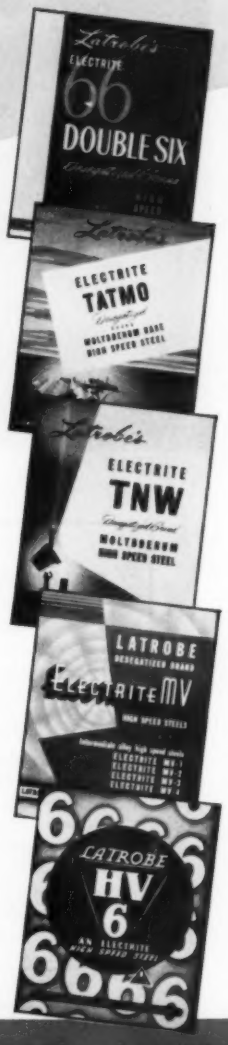
AMERICAN Brake Shoe COMPANY

ELECTRO-ALLOYS DIVISION
ELYRIA, OHIO

have YOU used these

LATROBE DESEGATIZED* BRAND
MOLYBDENUM
HIGH SPEED STEELS

*Trade Mark Reg. U. S. Pat. Office.



The foremost problem facing the metalworking industry today stems from the critical shortages that exist in many raw materials.

Sudden shifts from the use of old and familiar to relatively new and unfamiliar materials are sometimes necessary, therefore, to overcome these shortages and still meet the demands created by expanding production trends.

To assist the possible new—and the old—users of its Desegatized Brand molybdenum high speed steels—Electrite Double-Six, Electrite Tatmo, Electrite TNW, Electrite MV Series, and Electrite HV-6—the Latrobe Electric Steel Company has carefully compiled guides to their proper selection and use. These guides, in the form of pamphlets illustrated at the right, are complete and contain up-to-date information on the analyses, forging, hardening, tempering, testing, recommended uses and the available forms of each of these steels. Get in touch with your nearest Latrobe representative for copies or write direct to the main office in Latrobe, Pennsylvania.

And remember . . . . Latrobe's Desegatized Brand molybdenum high speed steels are fully uniform and free from harmful carbide segregates. This quality—found in all Desegatized Brand steels—guarantees greater tool and die efficiency—an important factor in your production program today!

BRANCH OFFICES AND WAREHOUSES: Boston, Buffalo, Chicago, Cleveland, Dayton, Detroit, Hartford, Los Angeles, Milwaukee, New York, Philadelphia, Pittsburgh, St. Louis, Seattle, Toledo.

SALES AGENTS: Birmingham, Dallas, Denver, Houston, Wichita.

LATROBE ELECTRIC STEEL COMPANY
LATROBE, PENNSYLVANIA

This New Controller Says "Hurry Up, Furnace!"

WITH production reaching toward all-time highs, this new P.A.T. 50 Control already is helping many key plants increase the output of their furnaces. Here's why:

This Control has something that's brand new in proportional, electric controllers. Called "rate action," this feature enables the Controller to act on the *speed* of swings in furnace load, as well as on their size and on the length of time they persist. Thus, if temperature changes gently, it is gently nudged back into line. But if it starts off vigorously—as when the furnace door is opened—P.A.T. 50 reacts vigorously. Then, when the change has been headed off, the Controller starts to back away. But "putting on the brakes" it brings temperature in line smoothly and rapidly.

Thus, "Rate Action" increases production because it reduces the length of time a furnace is off temperature.

Also, Proportioning and Reset Actions are more responsive than before. These two components stop the normal temperature swings which are started by changes in the size and permanence of the furnace load. Even without rate action, these increases would enable P.A.T. 50 to do a better-than-ever job. With rate action, results are superior to any previous electric control.

The News is in the Control Unit at bottom of panel shown at right. Earlier installations can be converted to P.A.T. 50 by replacing the Unit and making slight changes in the Controller.

For details, contact our nearest office, or write us at 4927 Stenton Ave., Philadelphia 44, Pa.

THESE furnaces and controllers are part of the slab-heating equipment with which The Timken Roller Bearing Company, Canton, O., conditions high-alloy steels for rolling. The Timken Company has used many earlier L&N Controllers. They find P.A.T. 50 is a further step forward, not only in guarding quality, but also in increasing production by shortening the off-temperature time.

MEASURING INSTRUMENTS · TELEMETERS · AUTOMATIC CONTROLS · HEAT-TREATING FURNACES

LEEDS & NORTHRUP CO.

Jrl. Ad ND4-660(1)

Metal Progress is published and copyrighted, 1951, by American Society for Metals, 7301 Euclid Avenue, Cleveland, Ohio. Issued monthly; subscriptions $7.50 a year. Entered as second-class matter Feb. 7, 1921, at the post office at Cleveland, Ohio, under the act of March 3, 1879.

Other engineers are finding many new uses for this new SR-4® device . . . *How about you?*

Further expanding the engineer's field of exact knowledge, the Baldwin SR-4 Fluid Pressure Cell opens entirely new opportunities in the precise measurements of both stable and fluctuating pressures in all types of fluids.

Heart of the cell is a pressure-sensitive tube with an SR-4 strain gage grid bonded to its exterior. Gas or liquid to be measured enters this tube, causing it to expand, which stretches the fine wire in the grid. The consequent alteration in electrical resistance, calibrated in p.s.i. or other units, is measured by an indicator or recorder, or actuates monitor or alarm apparatus.

The cell is easily installed, and is adaptable to use with all types of fluids—corrosive or non-corrosive—and over a wide range of pressures. A wide variety of indicating, recording and controlling instrumentation is available to meet your particular requirement. Calibration inaccuracy is not more than ¼% of full range at any point from 0% to 100% of capacity, and this measuring performance is maintained under hundreds of thousands of pressure cycles. The unit is extremely responsive to pressure fluctuations making it invaluable for research on surges and similar pressure fluctuations, and explosion studies. For more detailed information, ask for Bulletin 306. One of our representatives will be glad to discuss the application of these cells to the solution of any fluid pressure measurement or control problem you may have.

BALDWIN-LIMA-HAMILTON

TESTING HEADQUARTERS

EDDYSTONE DIVISION, BALDWIN-LIMA-HAMILTON CORPORATION, PHILADELPHIA 42, PA.

In Canada: Peacock Bros., Ltd., Montreal, Quebec

Are You Seeking a Supplier of ALUMINUM CASTINGS?

PERMITE

Here at Aluminum Industries, Inc., are proven facilities you can count on for supplying aluminum alloy castings of uniformly high quality, in any sizes and in any quantities you need. Just check and compare:

- One of the largest aluminum foundries in the United States for the production of Permanent Mold, Semi-Permanent Mold and Sand Castings.
- Ample capacity for immediate scheduling of your requirements.
- Well-equipped department for machining and finishing aluminum castings.
- Tool room, equipped with the latest type machine tools.
- Physical and metallurgical laboratory, equipped to maintain strict quality control and inspection standards.
- Pattern shop for pattern repair and maintenance.
- Engineering Department for application of the best engineering principles, all the way from the design stage to the finished casting.
- Ample warehousing facilities, favorably located for shipping.
- Secondary aluminum plant for the refining of scrap metals.
- Foundry personnel with the skill and "know-how" developed in over 30 years of experience in working with aluminum and its alloys.

Send for new bulletin telling how and why you can depend upon Aluminum Industries, Inc., for the aluminum castings you need in your production. Ask for Bulletin No. 20-A. Recommendations and estimates given without obligation.

ALUMINUM INDUSTRIES, INC.

CINCINNATI 25, OHIO

ALUMINUM PERMANENT MOLD, SAND and DIE CASTINGS...HARDENED, GROUND and FORGED STEEL PARTS

COPPER NAILS and TACKS
COPPER STORM NAILS

BRASS and BRONZE
BOLTS and NUTS

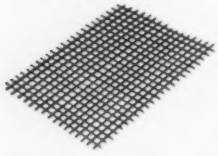
BRASS and BRONZE CAP
and LAG SCREWS

BRASS and COPPER RIVETS
and WASHERS

BRASS COTTER PINS
BRASS ESCUTCHEON PINS

SOLDERING COPPERS

INDUSTRIAL WIRE CLOTH and
BRASS STRAINER CLOTH



AUTOMOTIVE and
INDUSTRIAL FITTINGS

COPPER HAMMERS

BEARING BRONZE BARS

Miscellaneous items of copper and brass for M-R-O

at CHASE

Need Bearing Bronze Bars? Brass or Bronze Bolts? Copper Nails? Any other Brass or Copper Items for Maintenance—Repair—Operating Supplies? We can supply many such items under NPA Reg. 4 to any business enterprise, government agency, or public or private institution, on a DO-97 rated order for such uses, subject to the end use restrictions established by the NPA.

Chase offices (23 of them warehouses) located in major industrial centers, coast to coast, stand ready to serve you. Phone the one nearest you. They'll make every effort to fill your "DO" orders from stock or as soon as possible, if not from stock.

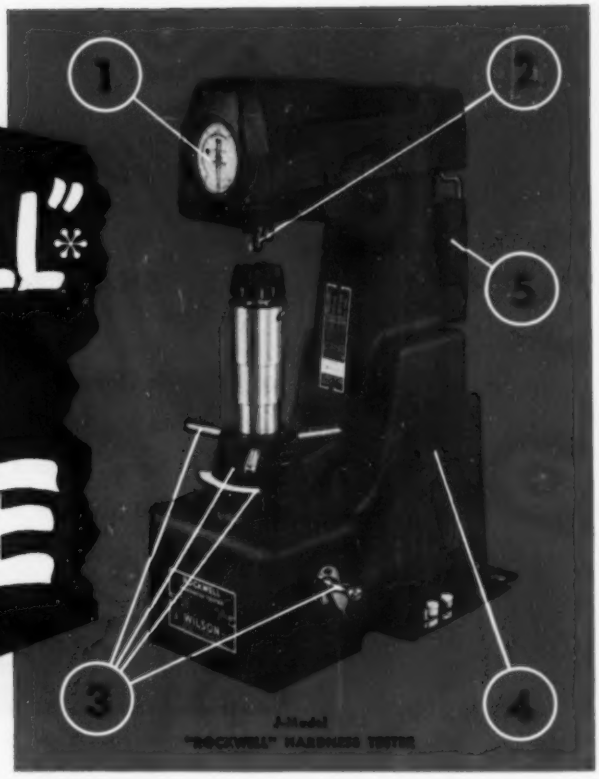
Chase BRASS & COPPER

WATERBURY 20, CONNECTICUT • SUBSIDIARY OF KENNECOTT COPPER CORPORATION

• *The Nation's Headquarters for Brass & Copper*

Albany†	Chicago	Denver†	Kansas City, Mo.	Newark	Pittsburgh	San Francisco
Atlanta	Cincinnati	Detroit	Los Angeles	New Orleans	Providence	Seattle
Baltimore	Cleveland	Hartford	Milwaukee	New York	Rochester†	Waterbury
Boston	Dallas	Indianapolis	Minneapolis	Philadelphia	St. Louis	(1 sales office only)

"ROCKWELL"* ...to be SURE



You NEED these features to assure accuracy and speed in hardness testing

1. Totally enclosed, dirt and dust-proof "Zerominder" dial gauge
2. Gripsel clamp screw for quick change and proper seating of penetrator
3. All controls grouped conveniently under capstan handwheel
4. Enclosed, easy-to-reach variable speed dash pot
5. Standardized weights

The J-Model improved "ROCKWELL" Hardness Testers have higher sensitivity, increased speed, are simpler to operate.

Most specifications today call for parts with certain hardness limits. If you test incoming materials, you know if they meet your production requirements. You know there will be fewer rejects. Then when you ship, you'll know that your customers will be satisfied.

"ROCKWELL" Hardness Testers are made in two types (Regular and Superficial) and many styles with accessories so they can be adapted to testing flats, rods, rounds, and odd shapes. There is also the TUKON for micro-indentation hardness testing. Tell us the nature of the test you contemplate, and we will recommend the machine best suited to the work.

*Trade Mark Registered

ACCO

TRADE MARK

WILSON

MECHANICAL INSTRUMENT DIVISION
AMERICAN CHAIN & CABLE

230-F Park Avenue, New York 17, N. Y.

"ROCKWELL" HARDNESS TESTERS

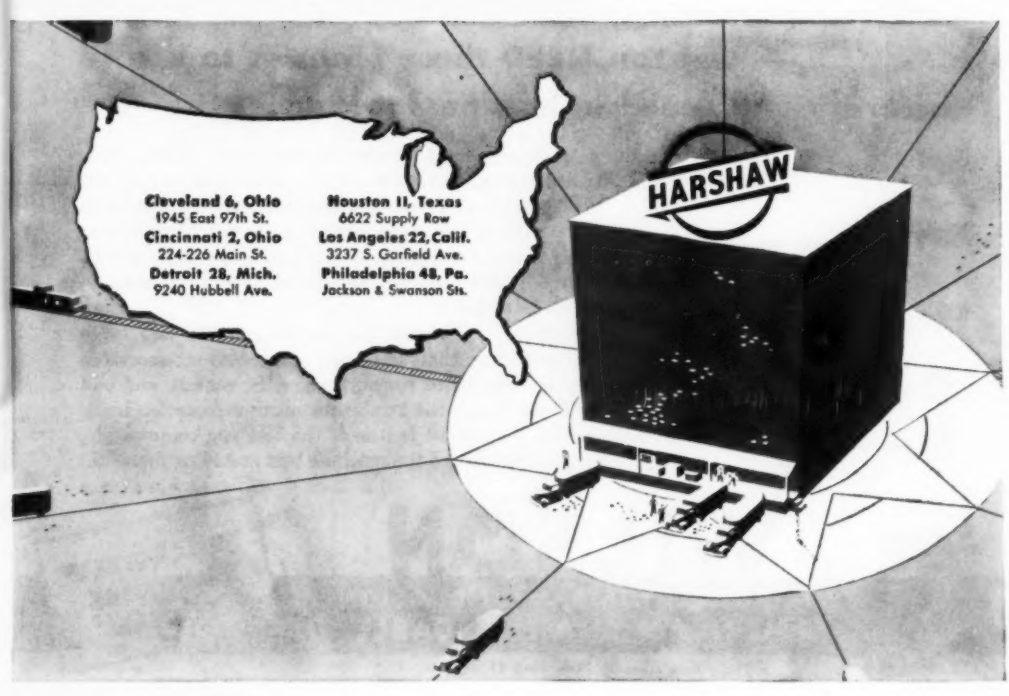
Make your Choice–

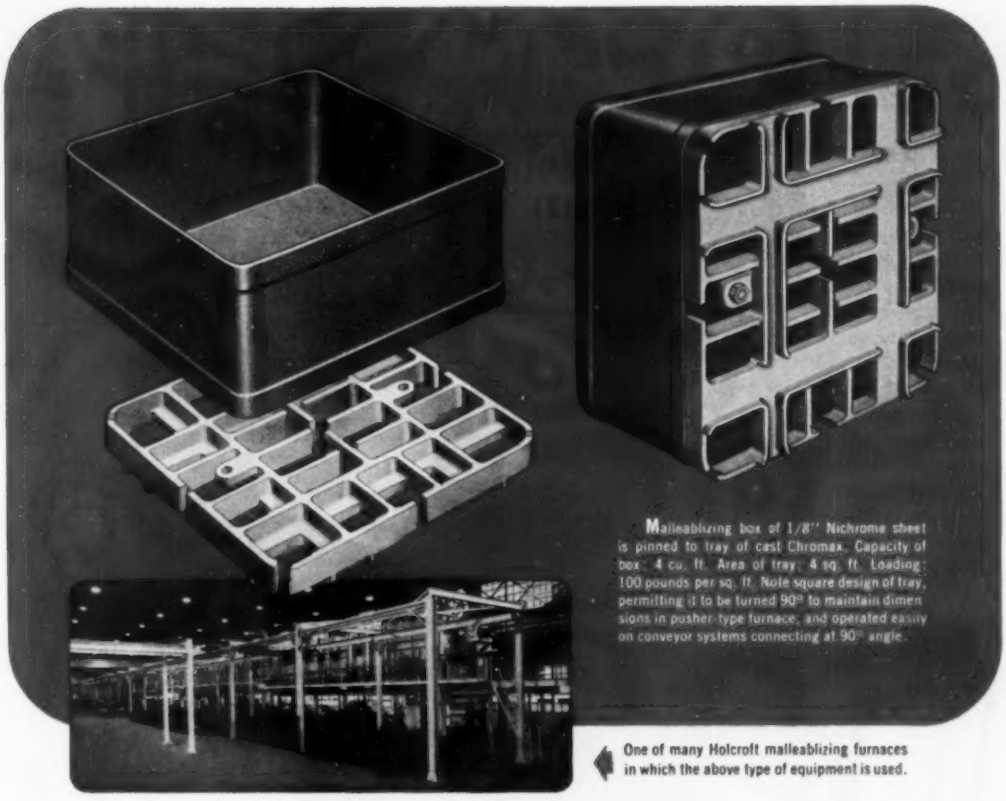
THEN DEPEND ON HARSHAW SCIENTIFIC TO SUPPLY IT

All 6 Harshaw Scientific Offices maintain warehouse stocks of laboratory instruments, apparatus, and chemicals—in fact, *thousands* of different items . . . good, recognized items.

We'll ship your material from our branch nearest you . . . and there *is* one within fast shipping distance of you.

HARSHAW SCIENTIFIC
DIVISION OF THE HARSHAW CHEMICAL CO
CLEVELAND 6, OHIO





Malleablizing box of 1/8" Nichrome sheet is pinned to tray of cast Chromax. Capacity of box: 4 cu. ft. Area of tray: 4 sq. ft. Loading: 100 pounds per sq. ft. Note square design of tray, permitting it to be turned 90° to maintain dimensions in pusher-type furnace, and operated easily on conveyor systems connecting at 90° angle.

One of many Holcroft malleablizing furnaces in which the above type of equipment is used.

How Live Load Ratio was improved 250%

A large midwestern implement foundry has proved that use of trays and boxes made of Driver-Harris alloys, for malleable annealing of small parts, results in outstanding savings in deadweight and better heat transfer. Production has been stepped up considerably by increasing live load and shortening the heat-treating cycle.

Hard cast iron boxes, formerly used in tunnel kilns, weighed 650 pounds each, and carried a maximum work load of 330 pounds—giving a load ratio of approximately 0.5 to 1.

Boxes in service today are fabricated from ⅛" Nichrome* sheet. These are pinned to specially designed trays of cast Chromax* (see illustration). Box load is 400 pounds. Total weight of a box and tray is 180 pounds. Thus load ratio is 400 to 180, or approximately 2¼ to 1.

Such a remarkable improvement in the ratio of live load to deadweight of containers (almost 250%) has, of course, resulted in proportionate improvement in efficiency—or fuel saving.

To date, these boxes and trays have given 36 months of service in a continuous malleablizing furnace. During this period, they have made 480 trips through the furnace—representing 480 heat and cool cycles. They have been in the furnace 22,640 hours, about 86% of the total elapsed time, under temperatures up to 1725°F. Each box has annealed 90 tons of work.

Neither boxes nor trays are showing any permanent distortion or embrittlement. In fact, they are performing as well today as when first put into service, and are proving conclusively that malleable annealing can be a clean, labor-saving, fuel-saving operation.

Here is but another example of how Driver-Harris alloys are being applied to great advantage in the heat-treating field. Why not consult with us for a solution to *your* heat-treating equipment and furnace part problems? Although the demand for D-H products in the present emergency is engaging the resources of this firm to an unprecedented extent, we shall be glad to serve you to the best of our ability.

Nichrome and Chromax are manufactured only by

Driver-Harris Company

HARRISON, NEW JERSEY

BRANCHES: Chicago, Detroit, Cleveland, Los Angeles, San Francisco

*T. M. Reg. U. S. Pat. Off.

CARMET

can solve *YOUR* *Wear-Resistance* problem

● **WHAT JOBS HAVE YOU FOR CARMET CARBIDES TO DO?**

For maximum wear, save with Carmet—preformed to practically any shape or size! *Examples:* entire blanking die parts; inserts for drawing, heading, extruding and blanking dies; gauge and wear parts, pins, bushings, etc. *Supplied Preformed*—with minimum grind stock allowed, or precision ground and ready for use. Let us work with you . . . send us your drawings and specifications for quotations. ● *Allegheny Ludlum Steel Corporation, Carbide Alloys Division, Wanda and Jarvis Avenues, Detroit 20, Mich.*

For complete **MODERN** Tooling, call

Allegheny Ludlum

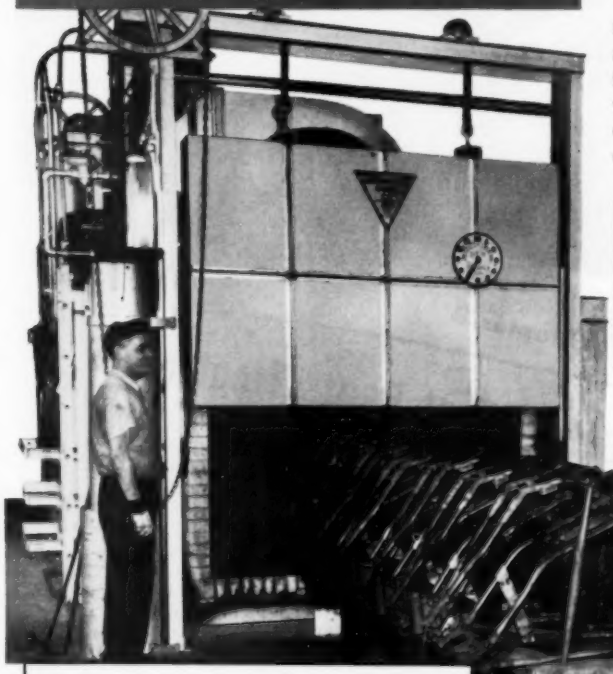
AL
FINE TOOL STEELS
SINCE 1854

W&O 3486

Harley-Davidson meets higher production schedules

DESPATCH

New, Double-end ANNEALING FURNACE Boosts Production 60% over old Methods



THE NATION'S EXCLUSIVE BUILDER OF MOTORCYCLES HAS AGAIN CHOSEN DESPATCH EQUIPMENT . . . Most recent DESPATCH installation is this gas-fired, forced convection air heated type, double-end furnace for annealing motorcycle frames, forks, handlebars, brake shells, etc.

Only steel is handled by the furnace and according to the foreman in charge, the percentage of production increase over the old furnace is 60%. Time saving has been bettered some 60% also, because of the short heat-up period of 20 minutes as compared to an hour with the old furnace. Another time-saving feature is the fact that the furnace can be loaded from either end.

Better quality to meet the firm's rigid requirements has been achieved due to the accurate temperature control and heat uniformity the furnace provides. It is equipped with electrical and safety controls, and the direct gas-fired heater is capable of producing 1,300,000 BTU's per hour.

CALL ON DESPATCH

DESPATCH furnaces are engineered to fit any industry, any heat application. Write to Dept. P for more information.

FOLLOWING ARE MOTORCYCLE APPLICATIONS EMPLOYING THE NEW DESPATCH FURNACE

- *Frames** 850°, 1¼ hr., #1035 steel.
- *Safety Guards*, 750°, 1 hr., #C1026 steel.
- *Brake Shells*, 725°, 1 hr., #1010 carburized.
- *Connecting Rods*, 400°, 2 hrs., #1045 steel.
- *Hub Shells*, 400°, ¾ hr., #1010 steel.

* The picture shows a load of motorcycle frames being pushed into the furnace for stress relieving; 15 per load, 5 loads per day.

DESPATCH OVEN COMPANY

Minneapolis Office: 619 S. E. 8th St.

Chicago Office: 4554 Broadway

ROUND AND SHAPED TUBING
(.010" to ⅜" O.D. Max. Certain Analyses .035" max. wall to 1⅜" O.D.) Available in
Carbon Steels:
A.I.S.I.—C-1008, MT-1010, MT-1015, C-1118, MT-1020, C-1025, C-1035, E-1095
Alloy Steels:
A.I.S.I.—4130, 4132, 4140, 4150, 8630, E-52100
Stainless Steels:
A.I.S.I.—303, 304, 305, 309, 310, 316, 317, 321, 347, 403, 410, 420, 430, 446, T-5
Nickel Alloys:
Nickel, "D Nickel"*, "L Nickel"*, "Monel"*, "K Monel"*, "Inconel"*, 30% Cupro Nickel, 18% Nickel Silver.
Beryllium Copper.
*Reg. U.S. Trademark International Nickel Company.

The HOLE Story —by— Superior

Chapter 2

The Bubble That Beats Trouble to the Punch

In science, the arts and industry, fine small tubing serves many purposes, from the hypodermic injection of healing drugs to the control of hydraulic presses that produce airplane and tank components.

In every tubing job there is one prime requirement. The tube must not leak. Here at Superior we specialize in the production of high quality tubing in all practical metals . . . and we use many methods to insure the superiority of our product.

Precision gauges in the hands of experienced inspectors check for dimensional precision. High powered microscopes in our laboratories investigate grain structure. Chemical analysis maintains close control on metallurgy. And in our shops compressed air, under pressures to hundreds of pounds per square inch, is forced into tubing held under water to make sure that leaks are detected and eliminated.

The whole story of Superior is one of quality . . . in machines and methods, in men, and in the end result —fine small tubing to do tough jobs well.

This is a story with continuity, for our aim holds always to raise the standards by which we judge Superior tubing . . . and to continue to increase the rate at which we produce it to meet your demands.

SUPERIOR TUBE COMPANY, 2008 Germantown Ave., Norristown, Pa.

West Coast: Pacific Tube Company, 5710 Smithway St., Los Angeles 22, Calif. UNderhill 0-1331.

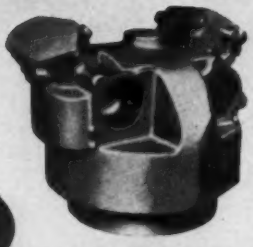
Pittsburgh Steel
announces new facilities for
Oil Tempered Wire
to better serve its customers
Now, Oil Tempered Wire has been added to the extensive line of manufacturers wire which Pittsburgh Steel Company has been serving to industry for nearly half a century. The same high Pittsburgh quality that stems from rigid control of its own raw material and long experience in steel production prevails in this new Oil Tempered Spring Wire.
Pittsburgh Oil Tempered Wire is available in a complete size range, either flat or round, in coils or straightened and cut lengths. Also, Pittsburgh hard drawn MB spring wire will be available in a complete range of sizes.
For Oil Tempered Wire and Hard Drawn MB Spring Wire that is uniform in size, finish, mechanical and metallurgical properties, specify Pittsburgh. Write now for information to Department IA, Pittsburgh Steel Company, Pittsburgh 30, Pa.
P
Pittsburgh Wire
A product of Pittsburgh Steel Company
The Steel Industry Needs Scrap—
Keep it Moving

NATIONAL FORGING MACHINES
For Deep-Piercing and Upsetting!

Aircraft Landing Gear Strut

Cluster Gear

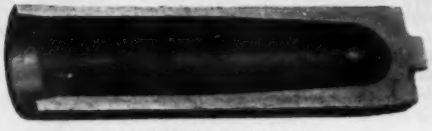
Truck Brake Spider



Aircraft Cylinder Head

Diesel Generator Quill

Shell Nose



Shell Body (Half Section)

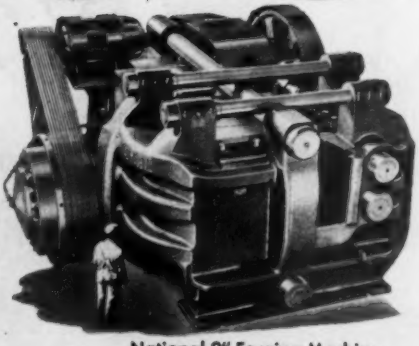
Aircraft Cylinder Barrel

Diesel Cylinder Liner

Aircraft Propeller Shaft

In World War II, the art of deep-piercing in Forging Machines came into its own. Forgings previously thought "impossible" were made routine by the pressing demands of war.

NATIONAL'S engineers and machines were "in the thick" of this forging development. Forgemen *still* choose NATIONAL Forging Machines for their difficult work . . . and *still* rely upon NATIONAL for assistance with their problems.



National 9" Forging Machine

NATIONAL
MACHINERY COMPANY
TIFFIN, OHIO.

DESIGNERS AND BUILDERS OF MODERN FORGING MACHINES—MAXIPRESSES—COLD HEADERS—AND BOLT, NUT, RIVET, AND WIRE NAIL MACHINERY

Hartford Detroit Chicago

Switching to TIMKEN® tubing saved 14% on this part!

THE cost of this automotive part was $150.90 per thousand when made from bar stock. When the manufacturer switched to Timken® seamless tubing, he was able to use boring tools in place of twist drills and to increase speed and feeds. This resulted in producing 144 pieces per hour instead of only 96, with the savings shown here:

COST FIGURES TELL THE STORY

	BAR STOCK	TIMKEN TUBING
Material cost per 1000 pieces . . .	$ 83.19	$ 84.71*
Machining cost per 1000 pieces (6 spindle 2⅝" capacity automatic screw machine with estimated operating cost of $6.50 per hour)	$ 67.71	$ 45.14
TOTAL COST . . .	$150.90	$129.85

Total with bar stock. . . . $150.90

Total with Timken tubing . $129.85

SAVING . . . . . $ 21.05 (14%)

*In most cases, Timken seamless tubing is lower in cost than bar stock, foot for foot. In this instance, it was slightly higher because of the extremely great wall thickness.

If you make a hollow cylindrical part, chances are you can save anywhere from 10 to 35% by switching from bar stock to Timken seamless tubing. Timken tubing eliminates drilling because the hole is already there. Finish boring is often your first production step. You have less stock to machine—less scrap loss. Machining cycles can be shorter, speeds and feeds increased.

And since the piercing process by which Timken seamless tubing is made is basically a forging operation, you get fine forged quality in your hollow parts. From tube to tube, and from heat to heat this fine forged quality is always uniform because of our rigid quality control.

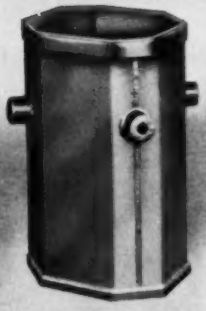
USE OUR TUBE ENGINEERING SERVICE

Our Tube Engineering Service helps you select the most economical tube size for your job, guaranteed to clean up. With the tube we specify, you waste no time or material machining away excessive stock. Yet, you're sure of enough metal to fill out your dimensions. For an analysis of your requirements, write The Timken Roller Bearing Company, Steel and Tube Division, Canton 6, Ohio. Cable address: "TIMROSCO".

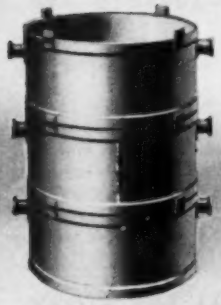
YEARS AHEAD—THROUGH EXPERIENCE AND RESEARCH

Specialists in alloy steel—including hot rolled and cold finished alloy steel bars—a complete range of stainless, graphitic and standard tool analyses—and alloy and stainless seamless steel tubing.

The original PSC carburizing box, now the most widely used in industry.

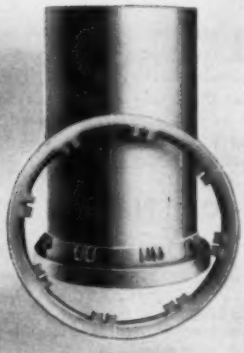


An example of the many special-purpose boxes we design and fabricate.



Special PSC retorts for small lots of different parts in gas furnaces.

Welded alloy retort for gas carburizing furnaces. Serving 10,000 hours.



PSC boxes that are light weight for easy handling, yet will not warp. In any size.

Chimney type boxes for carburizing ring gears, in any size.

PSC *furnishes* CARBURIZING CARRIERS *for* Every Product

As suppliers of the widest line of standard carburizing boxes, PSC can promptly furnish a standard type box for carburizing, for instance, ring gears of any size. But we also offer a wealth of experience in making special fixtures that will carry unusually shaped parts through carburizing and quenching to finishing, with only one handling.

PSC welded alloy carburizing boxes are used today by 80% of the nation's heat treaters. Weighing ⅔ less than cast equipment, they save handling as well as heat-up time. For instance, a study by a recent customer showed that PSC light-weight equipment cut their cycle a total of 5 hours. Lasts longer too.

Light Weight of PSC Carburizing and Annealing Equipment Cuts Heat-Hour Costs

Light-Weight **Heat-Treating Equipment for Every Purpose**

Carburizing and Annealing Boxes	Tumbling Barrels • Tanks
Baskets • Trays • Fixtures	Cyanide and Lead Pots
Muffles • Retorts • Racks	Thermocouple Protection Tubes
Annealing Covers and Tubes	Radiant Furnace Tubes and Parts
Pickling Equipment	Heat, Corrosion Resistant Tubing

PSC heat-treating units are furnished in any size, design or metal specification. Send blue prints or write us to your needs.

THE PRESSED STEEL COMPANY
of WILKES-BARRE, PENNSYLVANIA

Industrial Equipment of Heat and Corrosion Resistant WEIGHT-SAVING *Sheet Alloys*

☆ ☆ ☆ OFFICES IN PRINCIPAL CITIES ☆ ☆ ☆

Aluminum

Government regulations limit the use of aluminum for other than essential products. The facts presented here are to help you speed this essential work and get the most out of available metal.

becomes increasingly important to designers as they help America rearm. Alcoa presents useful information on its properties, available forms and production economies.

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Aluminum Die Castings
Finishing Aluminum
Aluminum Impact Extrusions
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Aluminum Extrusions

Aluminum Castings

Plaster molding, as practiced in Alcoa Foundries, offers designers important advantages in accuracy of parts, less finishing and machining.

For medium quantities, plaster castings offer definite advantages over sand, permanent mold and die castings. Surfaces are far smoother than sand castings — usually requiring very little or no finishing. While molding costs are higher than sand casting, Alcoa's production facilities make the per-part price usually lower than die or permanent mold castings for medium-length runs.

Thin sections can be cast in plaster molds. Dimensional tolerances of .005 per inch can be held easily. Machining usually can be held to an absolute minimum.

Alcoa Foundries currently produce automotive torque converters, impellers and aircraft accessory fittings by the plaster process. And since Alcoa casts both aluminum and magnesium by all methods, our specialists are in an excellent position to make totally unbiased recommendations of the process best suited to your particular part and quantity.

ALCOA

ALUMINUM COMPANY OF AMERICA • 1805F GULF BLDG., PITTSBURGH, PA.

Aluminum Die Castings

often cost less than die castings of any other metal. Their physical and mechanical properties suggest them for many rearmament jobs.

Aluminum's lighter weight permits more than twice as many castings per pound as heavier metals. The cost-weight ratio operates favorably in so many cases that economies are possible even in small castings. Exceptionally large die castings as produced by Alcoa are almost certain to cost less in aluminum.

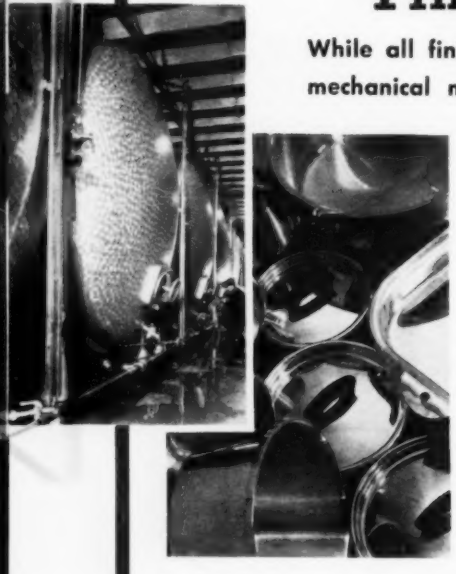
Alcoa Aluminum die castings offer substantial physical property advantages. Stability of dimensions through a wide temperature range and under sustained loads. High conductivity of heat and electricity. All of these advantages cannot be matched by other die-casting metals.

Examination of shop costs show other advantages of Alcoa Aluminum die castings. Machining is fast. Speeds and feeds are usually limited only by the capacity of the machine tools. Handling and shipping cost less.

These and other design considerations are covered in detail in Alcoa's 188-page designers' handbook, "Designing for Alcoa Die Castings." Write for your free copy.

Finishing Aluminum

While all finishing methods may be used, these simple mechanical methods require no large investments in equipment.



While most mechanical finishes are used for decorative effect, some have functional purposes. Preparing the surface for greater paint adhesion and increasing aluminum's reflectivity of light and radiant heat are examples of the latter. Any mechanical finish that can be applied to other metals can be applied to aluminum.

Buffing — Highly specular surfaces can be imparted to aluminum by simple buffing and coloring operations.

Scratch brushing — Soft, satiny effects can be achieved by using wire brushes of varying stiffness and metal hardness. Such finishes are used to increase aluminum's heat absorbing properties and to relieve the monotony of large areas.

Sand blasting — An easy method to produce a uniform, soft sheen to aluminum — to hide minor surface defects — to produce interesting high-light effects by masking.

Tumbling and burnishing — An extremely economical method for mass finishing of small parts. Ball burnishing produces smooth, lustrous surfaces.

All finishes for aluminum — chemical, electrochemical, painted and anodized — are described in detail in Alcoa's 63-page book, "Finishes for Alcoa Aluminum." Write for your free copy.

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Impact Extrusions

For the first time in the United States, Alcoa is producing double wall impact extrusions. This case history shows the important production savings they offer.

The manufacturer of this Navy signal flare part was faced with a production problem. Heavy investments in cost and time were required to make this product by welding two sections of tubing to an end plate.

Alcoa specialists suggested impact extrusion as a faster, more economical method of production. This process, which forms a cold slug into a hollow, cylindrical shape in an instantaneous press operation, has brought economies to many single wall parts. Alcoa facilities now produce the double wall one-piece part in a single, fast press operation.

Almost any symmetrical cup-shaped or hollow part can be impact extruded — complete with ribs, cavities and integral bosses in thin or heavy walls. If you have such a product that is not easily fabricated, formed or drawn, let Alcoa specialists work with you to explore the possibilities of impact extruding. Write for the free Alcoa book, "Alcoa Aluminum Impact Extrusions."

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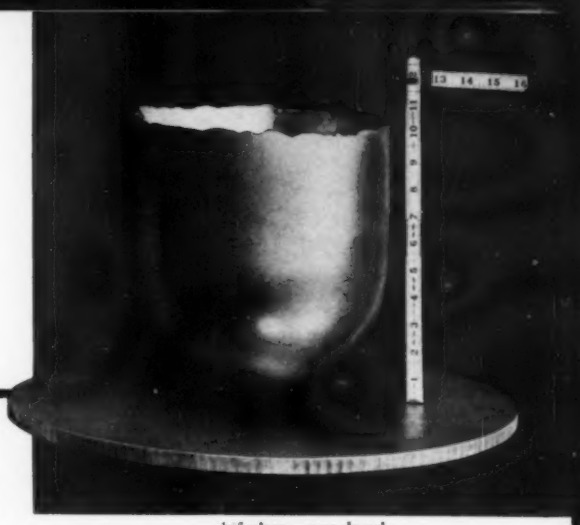
Magnesium

Deep, single draws . . . impossible in any other metal of equivalent strength . . . are easily accomplished by hot forming.



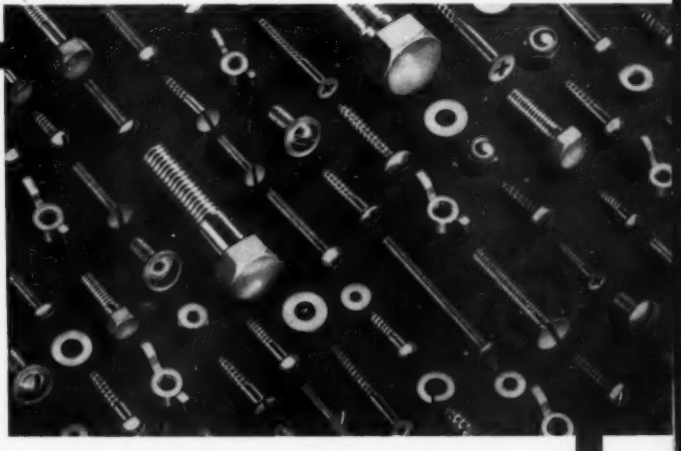
½" plate—one draw!

Reductions in blank size of 40% to 70% are not uncommon in magnesium when the stock and dies are heated. This propeller dome was drawn to a depth of 10" from ½" AMC52S-O in a single operation. The stock and dies were heated to about 600° F.

The production advantages of such deep draws are obvious. Die life is lengthened. Multiple stage dies are eliminated. Press time is cut. Spring-back is greatly reduced, with increased accuracy of parts. Annealing operations are no longer needed, for only one draw is required in most cases. Standard presses, furnaces and dies can be used. Only minor reductions in tensile and yield strengths result from preheating.

Alcoa's free, 329-page book, "Designing with Magnesium," describes deep drawing along with every phase of machining and fabricating. 6 pages of reference — 117 pages of tables — 178 pages of text — many illustrations, charts and diagrams.

Aluminum Fasteners



Both aluminum and non-metallic assemblies benefit from these lowest cost of all corrosion-resistant fasteners.

With more and more aluminum going into defense equipment, designers are becoming acutely aware of the importance of aluminum fasteners. They prevent galvanic corrosion that can occur when fasteners of dissimilar metals are used. They do not corrode from atmosphere or many chemical compounds.

ALCOA

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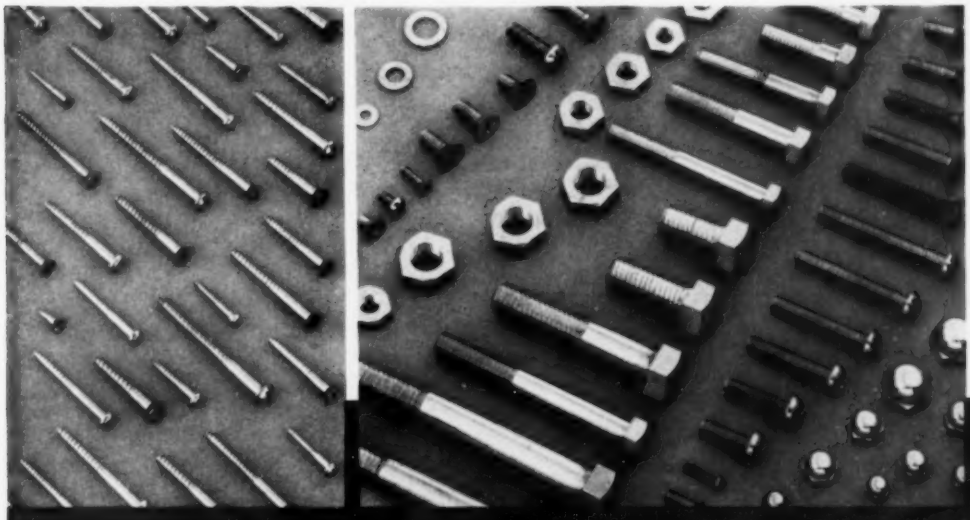
Fasteners (continued)

Alcoa makes a complete line of standard fasteners—can supply special fasteners to meet specific requirements. The Alcoa line includes sheet metal, machine and wood screws with choice of slotted or Phillips recessed heads; bolts and nuts of all standard sizes; cap, castle and wing nuts; washers, rivets and cotter pins.

Alcoa fastening specialists offer design help on questions of alloy selection, rivet driving methods and use of aluminum fasteners with other materials. Alcoa will gladly help you with your fastening problems.



Aluminum Screw Machine Stock

Alcoa has developed free-cutting alloys having high strength, good forming qualities, excellent corrosion resistance.

MAJOR ALLOY PROPERTIES
Alcoa 118-T3 — The best general purpose aluminum alloy for automatic screw machines.
Alcoa 178-T4 — Stronger than 118-T3 . . . best for deep hole drilling.
Alcoa 248-T4 — Stronger than 178-T4 . . . widely used for aircraft and other high-strength applications.
Alcoa 618-T6 — High corrosion resistance . . . especially suited to finishing by anodizing.

Rod, wire and bar of Alcoa Aluminum is available in these special alloys to give you a wide range of physical and chemical properties in the finished part.

Some have exceptional resistance to corrosive liquids and gases — are ideal for nozzles, couplings, valves, flanges, inserts, fasteners and similar components of equipment for the process industries.

Others offer higher mechanical strength or faster machining. All can be finished by any commercial method — mechanical, chemical, electrochemical, organic and inorganic coatings and anodizing.

With its 63-year aluminum background, Alcoa is in a unique position to assist designers of aluminum screw machine products in problems of alloy selection. Investigate through any Alcoa sales office, listed under "Aluminum" in your classified phone book.

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Aluminum Extrusions

permit placement of metal where maximum strength is needed... save greatly in material and fabrication costs.

Almost any shape can be produced by Alcoa — hollow, semi-hollow, solid. While cross sections must remain constant throughout the length of the shape, extrusions permit thick sections where stresses are concentrated — thin sections in areas of minor loading. In both metal cost and shop time, extrusions often can save substantially over roll forming or building up an equivalent section.

To help you visualize the almost limitless possibilities of aluminum extrusions, and to suggest ways you can adapt your designs to them, Alcoa has prepared a special booklet that's yours for the asking. Write for "Alcoa Aluminum Extruded Shapes."

Booklet offers basic design help...

- a discussion of design and production advantages of aluminum extrusions.
- examples of aluminum extrusions that have increased strength and stiffness because of efficient metal distribution.
- examples of designs that have been simplified by the use of a single extruded shape to replace expensive built-up assemblies, castings or machined sections.
- illustrations of the way several extruded shapes can be combined to simplify assembly and reduce costs.
- suggestions on modifying designs to utilize standard shapes and shapes for which dies are available.

ALCOA ALUMINUM

ALUMINUM COMPANY OF AMERICA • 1805F GULF BLDG., PITTSBURGH, PA.

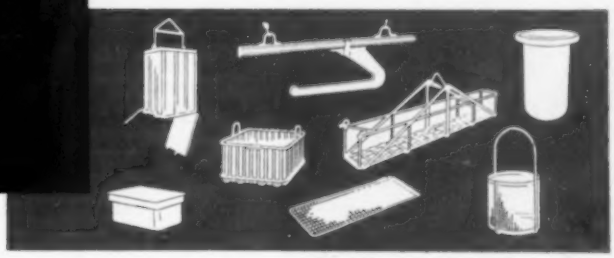
ROLOCK

FABRICATED ALLOYS

HEAT AND CORROSION RESISTANT

Saving CASE HISTORY NO. 2

Photo shows installation at the Bassick Co., Bridgeport, Conn., of a Rolock alloy Drop-Bottom Basket used with a pit-type furnace.



Rolock developed this fabricated drop-bottom basket for 2 reasons... to produce better work... to lengthen basket life, with consequent work-hour cost reduction.

Records show uniform heating with practically no rejects. Because the basket cover is closed and work is spilled out at bottom, distortion of parts and scratching are minimized. Draw pin is pulled for quench so that there's little exposure of work to cold air between heat and quench... then basket is reloaded fast and returned to furnace, retaining heat, increasing furnace capacity. Basket is not quenched with work... severe thermal shock is eliminated.

Such fabricated-welded baskets may be engineered to your job... fitted to your furnace. They give you highest resistance to cracked ammonia and carburizing atmospheres...handle greater load ratio to basket weight. Look to Rolock for greater dollar savings, better work in heat treating. Send for Catalog.

Offices in: PHILADELPHIA • CLEVELAND • DETROIT • HOUSTON • INDIANAPOLIS • CHICAGO • ST. LOUIS • LOS ANGELES • MINNEAPOLIS

ROLOCK INC. • 1222 KINGS HIGHWAY, FAIRFIELD, CONN.

JOB-ENGINEERED for better work
Easier Operation, Lower Cost

3RLB1

Metal WON'T Penetrate ...

TAYLOR ZIRCON hearths and side walls in aluminum remelting furnaces

Damage caused by penetration of hearth and side wall refractories by aluminum metal is the principal cause of furnace failure. As *Taylor Zircon* refractories are inherently *resistant* to "wetting" by pure aluminum and most of the aluminum wrought alloys, they are ideally suited for the construction of hearths and side walls in aluminum remelting furnaces.

But Taylor Zircon's properties don't stop there. Here are further advantages that pay off in cleaner metal—higher yield—longer furnace life:

- Contaminated or penetrated hearths are a source of inclusions and dirty metal. Taylor Zircon brick, bonded with thin, tight joints of Taylor Zircon Cement, are *not* penetrated by the metal. The metal remains clean, free from contamination by refractory inclusions.
- As Taylor Zircon contains a negligible amount of free silica, silicon pick-up is eliminated.
- Open hearth furnaces lined with Taylor Zircon can be cleaned or scraped, either h-o-t or cold, in *one-half* to *one-third* the time required to clean fire clay, superduty or high alumina brick lined furnaces.
- Metal composition can be changed without allowing for the loss of three or four wash heats. No metal will be trapped within or below the working face of the Zircon hearth, in a properly designed furnace.

Cleaning the interior of a 10-Ton Dempsey re-melt furnace, constructed with Taylor Zircon hearth and side walls, after having produced 13,800,000 lbs. of alloy No. 142 in approximately 10 months. Note the ease with which dross can be removed from the Taylor Zircon brick.

There are certain aluminum die cast alloys containing copper, silicon, magnesium and titanium for which zircon is not recommended. Your Taylor representative will be glad to discuss Taylor Zircon possibilities for your plant. Write for your free copy of Bulletin No. 202.

Refractorers to industry since 1864.

The CHAS. TAYLOR SONS Co.

MANUFACTURERS OF REFRACTORIES • CINCINNATI • OHIO • U.S.A.

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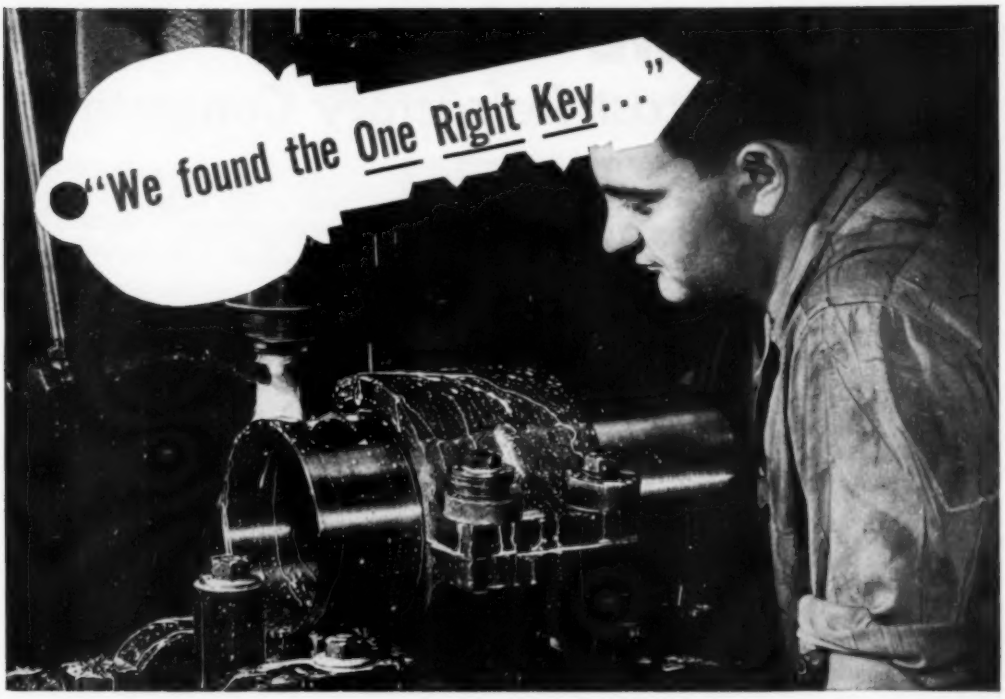

"It turned the trick for every cutting fluid problem in our shop"

"IN THIS ONE SHOP we had to do a whole range of different metal cutting operations. We couldn't get full answers every time from general lubrication guides. Guesswork was a threat to production," the superintendent said, "so I finally called in a Cities Service Lubrication Engineer."... What happened is this:

Individual operations were checked and classified. Special problems were ear-marked. After full study a plan was laid out covering general needs and specific tough points. These logical steps—based on Cities Service's wide experience in such matters—produced an actual cut in number of lubricants needed, without slighting the more difficult operations. They aren't so difficult now. The upshot is simplified routine—sharply clipped costs—gain in productivity.

Let a Cities Service Lubrication Engineer study your operations. His services are free. Products he recommends are backed by an unexcelled success record in industrial lubrication. Simply write or phone the nearest Cities Service office. There is no obligation.

A Complete Line of essential lubricants for the metal working industry.

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QUALITY PETROLEUM PRODUCTS

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Please send me without obligation your new booklet entitled "Metal Cutting Fluids."

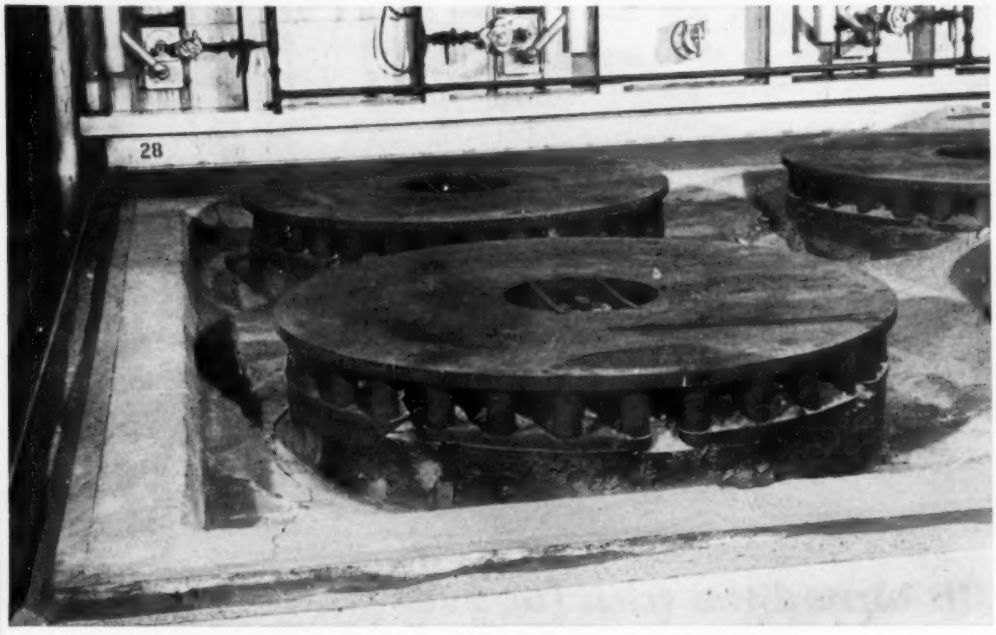
Name_____

Company_____

Address_____

City_____ State_____

SAVE TIME
with low cost Refractory Concrete



A GARY SHEET AND TIN MILL needed 4 new bell-type annealing furnaces. Engineers decided that Lumnite* Refractory Concrete was just what they needed for the 12 load-bearing bases, adjacent floors and curb because of their experience with Refractory Concrete on other jobs.

THEIR DESIGN was simple and efficient. Each base had 2″ of *insulating* Refractory Concrete for the bottom course. Over this was approximately 9″ of Refractory Concrete. Each load base houses a fan and electric motor which is protected from temperatures up to 1800°F by *insulating* Refractory Concrete.

Refractory Concrete did its job so fast that a program is now planned to rebuild 135 more bases with it.

Whether your plant uses bell-type annealing furnaces or not, chances are you can profit by using efficient Refractory Concrete, made with Lumnite calcium-aluminate cement. It is durable under extreme operating conditions and temperatures up to 2600°F. Low volume change in monolithic refractory concrete makes it highly resistant to thermal shock, and it reaches service strength in 24 hours or less!

Use it for furnace door linings, car tops, base pads, heat-resistant floors, metal-stack linings and, of course, there are many other uses.

FOR CONVENIENCE refractory manufacturers package mixtures of Lumnite and selected aggregates that are tailor-made to meet specific temperature and insulating requirements. These castables are sold by refractory dealers. For further information write: Lumnite Division, Universal Atlas Cement Company (United States Steel Corporation Subsidiary), 100 Park Avenue, New York 17, N. Y.

*"*LUMNITE" is the registered trade mark of the calcium-aluminate cement manufactured by Universal Atlas Cement Company.*

MP-L-49

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MORE UNIVERSALLY USED THAN ANY OTHER

Aluminum Heat Treating Method

. . . solution heat treatment or annealing

No other method can match these efficiencies!

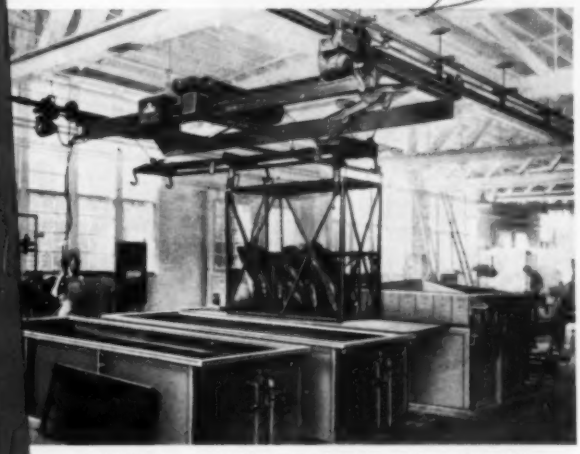
SPEEDIER PRODUCTION—Work comes up to required temperature almost the instant it is immersed in the bath. *More batches can be handled in far less time!*

MORE ACCURATE, MORE UNIFORM HEATING—Temperature does not vary more than 5°F. in any part of the bath. All parts of the work are heated quickly and evenly. Careful racking is not a problem. Because of fast, uniform heating, it is possible to charge simultaneously a wide variation of gage sizes requiring different heating cycles.

SIMPLIFIED QUENCHING—MINIMUM WARPAGE—Work from an Ajax Salt Bath can be removed and quenched in a matter of seconds, thus retaining the properties of the aluminum unimpaired. Pieces can be handled individually or in batches suspended in fixtures. Distortion of parts is reduced to a minimum and much expensive hand forming and straightening can be eliminated. An entire load need not be quenched at once, thus making it easy to keep a flow of parts to the next operation without storage refrigerators.

REAL PRODUCT PROTECTION—Because molten salt is the fastest heating medium known, grain growth is eliminated. The salt film eliminates oxidation and retards air chill on transfer to the quench. In handling clad metal, the fast, uniform heating avoids diffusion, so that corrosion resistant properties are unimpaired.

FAST, CLEAN—BUILT TO LAST—The fast production obtainable from an Ajax furnace cuts costs materially. The furnaces are clean. They're easy to operate without skilled labor. Ten or twelve years of continuous operation without pot, electrode or other failure has been the universal experience of Ajax users.



Solution heat treatment of large stampings. Tramrail hoist equipped with cage fixture transfers work from salt bath (at right) to water quench and finally to water rinse tank.

During World War II, Ajax Electric Salt Bath Furnaces were used by virtually every leading aircraft component and equipment manufacturer for heat treating aluminum parts.

More salt baths were used for aluminum solution heat treating than any other furnace type—and this same strong preference is equally evident in today's defense production program.

As proved in hundreds of installations, the Ajax Electric Salt Bath offers outstanding advantages in this field—from heat treating rivets, gussets or short extrusions to large formed parts such as ribs, stretched skins or almost any other aircraft aluminum component.

If it's aluminum, the record proves it can be heat treated better, faster, more accurately and more efficiently the Ajax Salt Bath way!

AJAX ELECTRIC COMPANY, INC.

WORLD'S LARGEST MANUFACTURER OF ELECTRIC HEAT TREATING FURNACES EXCLUSIVELY

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AJAX ELECTRIC SALT BATH FURNACES

Steel saved civilization at Augsburg

FOR 2000 years, the western world has survived vast waves of Asiatic invaders who threatened to destroy it. Repeatedly, the fate of civilization and Christianity has seemed to hang on the outcome of a single battle.

Such a decisive action was fought at Augsburg, South Germany, in 955 A.D. Swarming out of Asia, savage Magyars overran the rich Danube Valley. They ravaged the prosperous lands of Germany, Italy and France. At last, under Otto, King of Saxony, the armored Knights of Christendom rallied. They faced a hundred thousand fierce foes. The battle raged all day. Thousands were slain. At last the tide turned and the Magyars fled. For three days the Knights pursued the scattered enemy, killing or capturing thousands more. Symbolic of the west's predominance in weapons and armor of iron and steel, victory was credited to King Otto's iron-tipped Holy Lance.

Augsburg ended the Magyars' attempts to conquer Europe. They settled down to peaceful living in their valley and within 50 years accepted Christianity. Again, history demonstrated the truism that no people or alliance can establish supremacy unless it first predominates in the production and use of iron and steel.

It is reassuring that America produces twice as much steel as the rest of the world combined. America has the steel to win. We will use enough of it to protect our leadership of a free Christian world.

Scrap Metal is Critical Again

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make it
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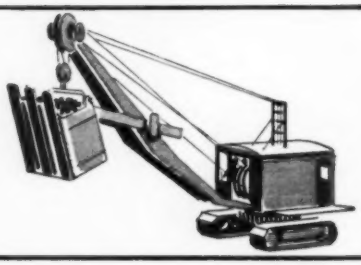

with

INLAND

HI-STEEL®

HI-STEEL GOES FARTHER. With proper design, three tons will ordinarily produce the same number of units formerly requiring four tons of ordinary carbon steel.

HI-STEEL REDUCES DEADWEIGHT. Its high strength-to-weight ratio permits reduction of sectional thicknesses without corresponding decrease in strength.

HI-STEEL IS TOUGH. Nearly twice the yield point of structural grade carbon steel. Higher notch toughness, fatigue strength, abrasion resistance.

HI-STEEL IS DURABLE. Its tight scale resists atmospheric corrosion four to five times as long as ordinary structural grade carbon steel—and has been known to perform 12 times as long under abrasive conditions depending on the abrasive medium.

HI-STEEL IS EASY TO WORK. It can be fabricated hot or cold, punched or drawn, welded or riveted—with little or no change in standard shop practice.

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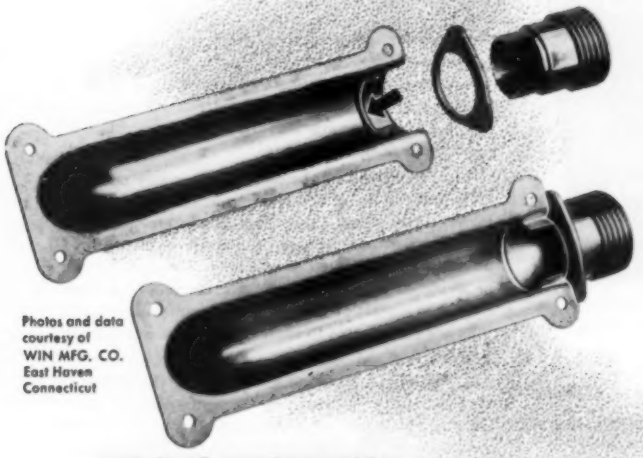
SALES OFFICES: Chicago, Davenport, Detroit, Indianapolis, Kansas City, Milwaukee, New York, St. Louis, St. Paul.

PRINCIPAL PRODUCTS: Sheets • Strip • Tin Mill Products • Bar Mill Products • Plates • Structural Shapes • Floor Plate • Piling • Reinforcing Bars Rails and Track Accessories • Pig Iron • Coal Chemicals.

For FAST, EASY, LOW-COST BRAZING you can't beat... EASY-FLO

■ You can get any metal joining production you need with EASY-FLO — and get it with the greatest of ease. For this unusually free-flowing, fast-penetrating, low-temperature silver brazing alloy makes fast production brazing as easy as ABC. A good example is illustrated — an illuminating gas meter part, which has to be 100% gas tight. With the simple set-up shown at right, working two 8-hour shifts with one girl per shift, they braze 2600 a week — and they tell us this output could be easily increased.



Photos and data courtesy of WIN MFG. CO. East Haven Connecticut

HERE'S HOW IT IS DONE

Two stampings and a screw machine part are joined with a half ring of EASY-FLO (arrow). Operator takes parts from cleaning bath – assembles them on positioning fixture with alloy half-ring preplaced at joint – applies flux – places assembly on brazing fixture and moves it into position under gas-air burners. Heating is automatically timed. By preparing assemblies while others are heating, operator turns out a steady stream of brazed parts.

In the finished part at left, note the neat, clean joint and the complete alloy penetration all through the joint area – one of the main reasons why EASY-FLO brazed joints are always leak-tight and stronger than the metals joined.

GET THIS INFORMATION-PACKED NEW BULLETIN 20

This bulletin gives you, not only the whole remarkable EASY-FLO and SIL-FOS brazing story, but also a lot of useful information about joint design and fast heating and brazing production methods. It's full of illustrations that contain ideas you can put to good use. Write for a copy today.

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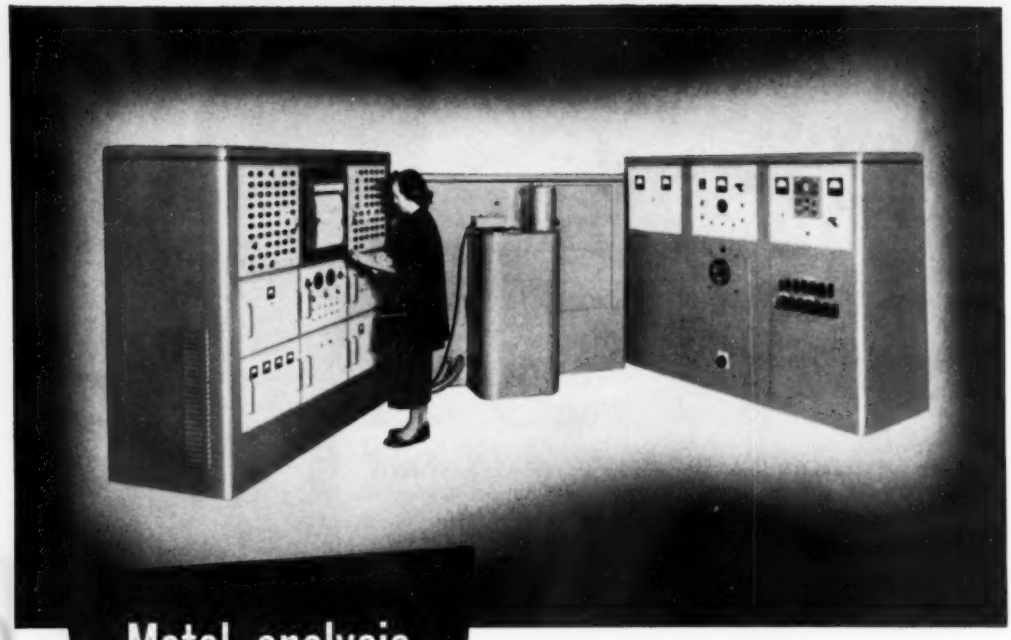

Metal analysis in 2 minutes...

with ARL Production Control Quantometer

Representing the most advanced type of direct-reading spectrometer yet developed, this multiple-purpose instrument provides pen-and-ink recorded analyses of samples, element by element, almost instantaneously. These graphic records may be made in multiple for high-speed analytical control.

The instrument can be designed for many purposes, including testing of metal alloys and other inorganic materials. As many as 25 elements can be measured with one instrument—up to 20 simultaneously. Individual units are not limited to one type of analysis but can be designed for diverse and versatile service to meet the requirements of several major plant problems. Results are comparable to chemical analyses in accuracy.

The latest and most elaborate unit in the complete ARL line of spectrochemical equipment, the ARL Production Control Quantometer offers the modern scientist the equivalent of a complete laboratory in one compact unit. Manufactured by the world's oldest and largest producers of direct-reading instruments, the Quantometer is available to help you in your analytical and production problems. Write for complete details.

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No other instrument in this field offers you so many outstanding features for obtaining complete, accurate, high-speed chemical analyses.

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ARL Production Control Quantometers are in daily use in all fields of metal analysis.

APPLIED RESEARCH LABORATORIES

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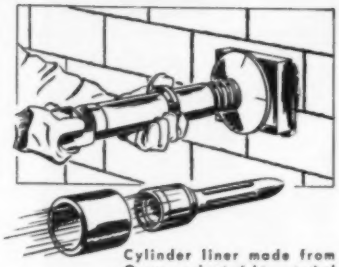
Tool Steel Topics



Cylinder liner made from Omega and, at right, a typical stud used in the Drive-It Tool.

Omega Tool Steel Takes 25-Ton Wallop in Novel Power Tool

Omega is our champion tool steel for cold-battering jobs, wherever there are heavy and repeated shocks.

In the Drive-It Tool, for example, it solved an unusual problem involving very heavy blows. This power tool, made by Powder Power Tool Corp., Portland, Ore., drives studs and rivets into concrete, masonry, even steel — eliminating drilling and hammering. It's fired by small-calibre cartridges, driving studs (made from Bethlehem Alloy Steels) as deep as 3 inches in concrete or through ⅝-inch steel.

Each type of stud used in the Drive-It Tool is designed so that a flange on its head is sheared off as the stud is shot through a cylinder liner pressed into the barrel. However, when liners began to crack under the stress of 25-ton blows, the makers realized that the oil-hardening tool steel they'd been using just didn't have enough shock-resistance.

Omega licked the trouble, thanks to its super toughness. Heat-treated to a hardness of Rockwell C-55 to C-57, the Omega liners put a stop to the breakage.

Omega is a tool steel engineered to take the heaviest shocks in its stride. Use it for tools and parts like these: punches, chisels, rivet busters, shear blades, swaging dies, gripper and vise jaws, clutch parts, calking tools, and knockout pins.

Its typical analysis:

C	Mn	Si	Mo	Va
.60	.70	1.85	.50	.25

Sand-Cored Holes Easy to Ream with 67 Chisel

A foundry reported poor results with reamers used to clean up holes for shafts and bearings in iron castings. Made with sand cores, the inside surfaces of the holes are extremely abrasive to ream because of adhering sand.

The small-diameter reamers they were using were made of carbon tool steel; these hardened through because of their small section. Consequently, they were brittle — and breakage was terrific. The cutting edges of the larger reamers, also made of carbon tool steel, stood up pretty well, but because many of the reamers were quite long, the heat-treatment caused them to warp out of line.

Then they tried using high-speed steel. Still no real improvement. Reaming costs remained a headache, and they wanted a solution fast.

We tackled the problem by suggesting the use of 67 Chisel, Bethlehem's chrome-tungsten grade of shock-resisting steel. We don't always come up with the right answer in a hurry, but in this case the recommendation proved just what was needed. The first trial was a big success. Subsequent use of reamers made from 67 Chisel left no doubts, and so the foundry folks are pretty happy with their new reamers.

The secret of this solution was in the carburizing of the tools by heating to 1750 F, packing them in a box with a carburizing compound and holding one hour at that temperature. This treatment resulted in a nice high-carbon case which varied in depth from .005 to .008 inches. The cutting edges have a high hardness, but still retain the tough, shock-resisting core (about .50 carbon) which is characteristic of Bethlehem's 67 Chisel.

Its typical analysis:

C	Si	Cr	W	V
.50	.75	1.15	2.50	.20

Our Tool Steel Engineer Says: *Carbon tool steels are safest when hardening produces a case and a core*

Carbon tool steels are normally used so they'll harden with a case and a core. If tool sections are small, usually less than ½ in., the tools will harden all the way through . . . without the formation of any core. This is dangerous because such tools are likely to crack in heat-treatment.

Even more likely to crack is the tool having one portion that hardens with a case and a core . . . and an adjacent section which hardens through. A ring die, for example, with a body large enough to harden with a case and core will invariably crack in heat-treatment *if* it incorporates a flange which is thin enough to harden through.

Manganese, oil-hardening tool steel — such as our popular BTR grade — is just the thing for tools having a design likely to cause cracking when made from carbon tool steel. Air-hardening tool steels provide the greatest safety of all.

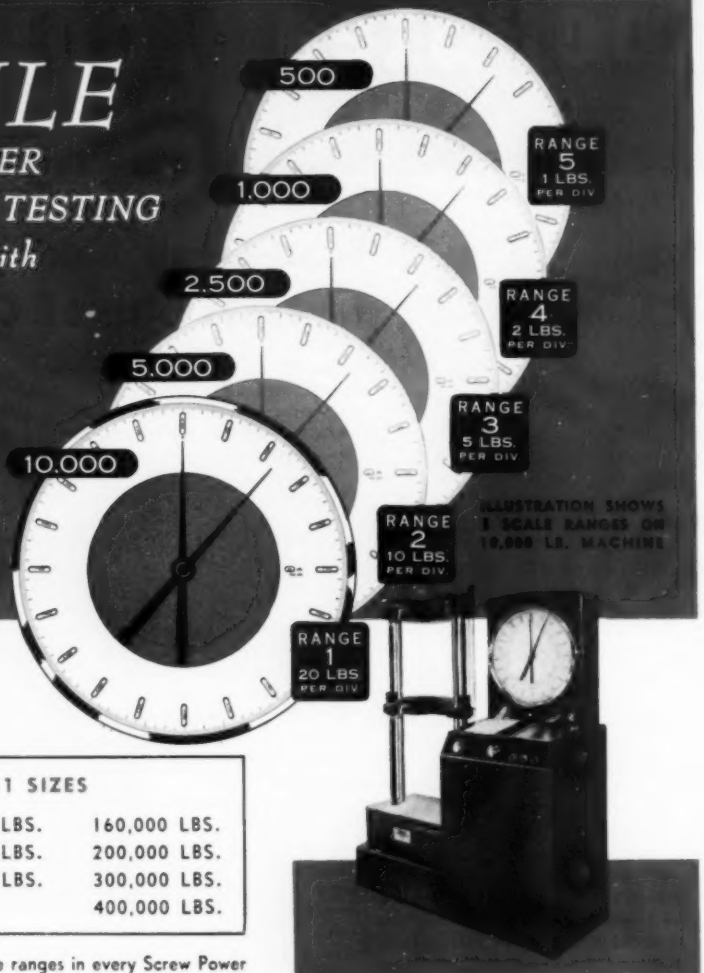
Bethlehem ULTRASONIC TESTED **Tool Steel**

RIEHLE

SCREW POWER UNIVERSAL TESTING MACHINES with

5 SCALE RANGES

PRECISE LOAD INDICATION FOR ALL YOUR TESTS


500
RANGE 5 1 LBS. PER DIV
1,000
2,500
RANGE 4 2 LBS. PER DIV
5,000
RANGE 3 5 LBS. PER DIV
10,000
RANGE 2 10 LBS. PER DIV
RANGE 1 20 LBS. PER DIV
ILLUSTRATION SHOWS 5 SCALE RANGES ON 10,000 LB. MACHINE

BUILT IN 11 SIZES

2,000 LBS.	30,000 LBS.	160,000 LBS.
5,000 LBS.	60,000 LBS.	200,000 LBS.
10,000 LBS.	120,000 LBS.	300,000 LBS.
20,000 LBS.		400,000 LBS.

Only Riehle gives you 5 separate ranges in every Screw Power Universal Testing Machine . . . the equivalent of 5 complete machines in 1.

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Other Riehle features you'll like are the fool-proof Pendomatic Indicating Unit . . . accuracy guaranteed within ½ the normal tolerance allowed by ASTM and Federal specifications . . . exceptionally low weighing table . . . low over-all height . . . easy installation and distinctive streamlined appearance.

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Engineering Digest of New Products

INDUCTION FORGE HEATER: Featuring speed and flexibility, the new Ajax-Northrup induction forge

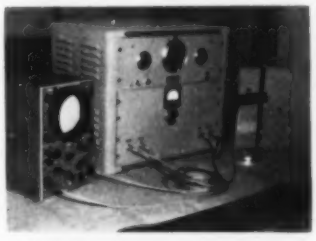
heating equipment automatically heats a wide range of billet sizes and shapes to a variety of pre-selected heating patterns. Three of these equipments, each with a power range of from 50 to 1500 kw., 400 to 800 volts and 3000 cycles, are now in use heating steel bar stock for automotive forgings. Billet sizes from 1 to 4 in., either round or square, can be handled, and are heated to 2250° F. at a maximum rate of 7500 to 8500 lb. per hr. Each equipment has space for eight heating stations with some 30 interchangeable heating units to accommodate the different sizes of bars. Each heating station has its own transformer, capacitors, push buttons, signal lights, automatic timers, hydraulically operated billet feeding devices, and protective relays; yet they can be arranged to work together in a wide variety of combinations to feed uniformly heated billets to the forge at a rate timed for maximum production.
For further information circle No. 478 on literature request card on p. 768B

CLEANING PROCESS: The Magnus Chemical Co., Inc., offers its Emulso Clean process as an efficient method of removing contaminants resulting from metal processing operations. Although not developed merely as a substitute for vapor degreasers, it is being used with complete satisfaction by metal finishers who have experienced difficulty in obtaining trichlorethylene or perchlorethylene. The new process is especially effective for removing smut, lithopone, chalk, tripoli, chlorinated and sulphurized oils and other stubborn contaminants. The process utilizes an emulsion cleaner supplied in concentrated form to be mixed with safety solvent. This neutral, oil and water soluble penetrating agent is noninflammable at working temperatures.
For further information circle No. 479 on literature request card on p. 768B

QUENCHING-AND-CONVEYING UNIT: Quenching-and-conveying equipment designed for continuous heat treating of individual pieces has been announced by the Klaas Machine & Mfg. Co. The oil in the tank is recirculated and cooled. The metal belt allows the quenched parts to drain as they move up the inclined conveyer, which is driven by a self-

contained power unit. Cleats or flights can be attached. Over-all dimensions: length, 8 ft.; width, 2 ft.; height, 4 ft. Larger quench-conveyers can be built for larger, heavier parts.
For further information circle No. 480 on literature request card on p. 768B

VIBRATION TESTER: The Electro Sonometer, by Electro Products Laboratories, Inc., is a new device for measuring the torsional and flexural characteristics of metals. The equipment consists of a precision oscillator, an extended range amplifier, a mechanical driver unit, a crystal pick-up and an amplifier resonance indica-

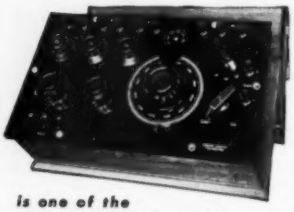


tor. Measurements are easily made; the driver is placed at one end of the sample under test and the pick-up at the other. Sufficient power is fed into the driver to cause the sample under test to vibrate. By tuning the oscillator through its frequency range, the point of resonance is indicated, and the mode and node of vibration and the phase relationship between the driver voltage and the pick-up voltage can be shown with the aid of a cathode-ray oscillograph.
For further information circle No. 481 on literature request card on p. 768B

MILLIVOLTMETER: An indicating millivoltmeter that contains a galvanometer unit, providing greater versatility and accuracy, is being introduced by Minneapolis-Honeywell Regulator Co. The unit is comparatively free from the effects of vibration and from varying lengths of extension wires. It can be actuated by thermocouples, resistance thermometers or any source of millivoltage.
For further information circle No. 482 on literature request card on p. 768B

VACUUM LEAK DETECTOR: A new and extremely sensitive leak detector for use in vacuum systems down to one micron Hg has just been announced by Distillation Products Industries. The new detector is expected to appeal particularly to those who have only occasional need for a leak detector and whose purpose is merely

Precise
TEMPERATURE MEASUREMENT



is one of the many applications of the
TYPE B HIGH PRECISION POTENTIOMETER

...a general purpose potentiometer with a number of notable refinements, suiting it particularly to thermocouple work. Distinctive features include:

- Three ranges —0 to 16 millivolts, 0 to 160 millivolts and 0 to 1.6 volts.
- Three reading dials—effective scale length of approximately 175 feet for each range.
- Subpanel switch and slidewire construction for protection of contacts from dust and corrosive fumes.
- Special provisions to minimize parasitic thermal emf's—including automatic compensation of slidewire thermals and gold contacts in galvanometer key.
- Exceptional convenience in reading and adjustment.
- Solid and substantial construction for many years of trouble-free service.

This standard laboratory potentiometer is also well suited for meter calibration, for checking portable potentiometers, and for other critical measurements of D.C. potentials requiring exceptionally high accuracy.

Described in Bulletin 270

SPOTLIGHT GALVANOMETER FOR SHOP AND LABORATORY WORK

- Sturdy, short period
- Sensitive (up to 1.5 μV per mm.)
- Multiple-reflection optical system
- 100-Millimeter scale
- For null or deflection measurements

Described in Bulletin 320

RUBICON COMPANY
Electrical Instrument Makers
3758 Ridge Avenue • Philadelphia 32, Pa.

Engineering Digest of New Products

to establish the presence of a leak too small to be detected by more obvious signs. In operation the sensitive tube of the leak detector is sealed into the system under test and the system is then pumped down to a moderate vacuum. A jet of harmless Freon gas or other halogen-containing gas is then directed against portions of the system suspected of leaking. When the jet strikes a leak there is a sudden deflection of the meter needle on the instrument face, because the gas entering the system instantly increases the ability of a hot platinum anode in the sensitive tube to emit positive ions.

For further information circle No. 483 on literature request card on p. 768B

BLACK OXIDE PROCESS: The Mitchell-Bradford Chemical Co. announces a new black oxide process for iron and steel known as Black Magic (Type A), a one-bath, one-salt process that operates at 290° F. Because of the lower operating temperature and the low concentration of salt (6½ lb. per gal.), the solution is highly fluid and this results in a minimum of loss from drag-out. The solution is self-rectifying and will rectify build-up of colloidal red iron oxides in the bath and other contaminants which might inadvertently be introduced.

For further information circle No. 484 on literature request card on p. 768B

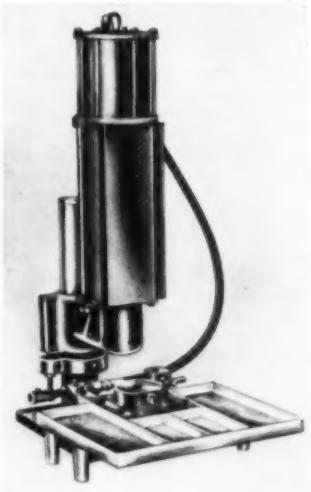
ABRASIVE FINISHING: A new metalworking procedure in the fields of high-speed, accurate deburring, descaling, stock removal and general surface finishing is now available through the use of the Cro-Hone pressure-blast, a self-contained wet-blaster manufactured by Cro-Plate Co., Inc. In operation, the work to be finished is inserted in the 30 x 30-in. cabinet through front hand-holes or side doors. Mechanical, knee-actuated valves and controls are within easy reach at the front of the cabinet, and a large window enables the operator to watch the work.

For further information circle No. 485 on literature request card on p. 768B

ELECTRICAL STEEL: A new, thin electrical steel has been developed by Armco Steel Corp. Known as Tran-Cor T-O-S, it can be operated at very high inductions, 20% higher than any nickel-iron alloy. The new material, thinner than most electrical steels, is intended for use in wound-type transformers and reactors which operate at 400 cycles. Its minimum permeability at 18 kilogausses is 1800. The new steel is an iron-silicon alloy with a high degree of orientation. It has a volume resistivity of 47 microhm-cm and a lamination factor of 95% solid. The strip can be bent flat over a small radius, then straightened without cracking, and easily slit or sheared.

For further information circle No. 486 on literature request card on p. 768B

STAKING PRESS: An improved air-powered bench-type press, for light staking, forming, riveting, punching and similar operations, is announced by Winter Products, Inc. This new press can optionally deliver as many as 60 spring-powered blows per minute with variable impacts up to 12,000



lb., or an adjustable air-powered squeeze up to 12 times the airline pressure. The 10 x 4½-in. throat accepts large work, and the stroke is adjustable from 1 to 2 in.

For further information circle No. 487 on literature request card on p. 768B

ELECTRIC FURNACES: To match the need for single units that do the work of multiple equipment over the full range of heat treating temperatures, Pereny Equipment Co. has introduced the new Pereco FG series

electric furnaces in various load capacities. These general-purpose units, equipped with Globar heating elements, are designed for heavy and continuous duty at all temperature levels up to 2500° F., with higher temperatures available for short or intermittent runs. Each of the furnaces has a separate, matching control panel unit, complete with indicating controller, transformer, current input meter with push-button reading, and magnetic contactor. Maximum connected load of the FG furnaces ranges from 9 to 50 kw. Loading areas range from 8 x 10 x 4 in. to 16 x 30 x 12 in. **For further information circle No. 488 on literature request card on p. 768B**

PLANER-MILLER: A new combination planer and miller built to handle large work is announced by the Giddings & Lewis Machine Tool Co. In this new machine are combined engineering features designed to simplify the setup and the machining of huge parts and assemblies. The machine will receive work 126 in. wide, 108 in. high and 26 ft. long.

To increase the flexibility of the combination machine, a right and left-hand planer head is mounted on the rail. These may be operated individually or simultaneously. In addition a right-hand planer side head is used to give the machine conventional planer advantages. The rail heads may be traversed to clear the entire table for a vertical milling head also mounted on the rail. Similar to the planer heads, the milling head may be swiveled to reach angular surfaces on the part being machined. A left-hand milling side head is provided to augment the regular machine functions. This head also swivels and is capable of reaching surfaces on the side of the workpiece.
For further information circle No. 489 on literature request card on p. 768B

WELDER: A new portable, semi-automatic manual machine for the Unionmelt welding of short seams is announced by Linde Air Products Co. The new machine, the UWM-1, can be used on work which cannot be welded conveniently with fully automatic machines. The parts of the UWM-1, which include the welding head, a voltage control box and a 75-lb. capacity spoke-type rod reel, are mounted on a small steel chassis equipped with casters, and a lifting eye. Automatic control maintains constant welding voltage even though the welding operator does not hold the hand unit at a uniform distance from the work. Operators need no special training.
For further information circle No. 490 on literature request card on p. 768B

● Up to 2 or 3 feet per second or 30,000 to 50,000 feet per 8-hour day, with one operator—is the production of Yoder resistance-weld tube mills.

Since the introduction of these mills only 12 years ago, the manufacture of high quality tubing has become so economical that it has virtually created a new industry—tubular metal furniture—and profoundly influenced product design in many other industries.

As a result, the demand has increased faster than the supply, so that Yoder pipe and tube mills today, more than ever, offer attractive investment possibilities.

Many manufacturers find it profitable to make tubing for their own use, others for resale.

Send for 68-page book, a practical treatise on pipe and tube making, answering many pertinent questions on tube mill operation, production, cost, etc.

THE YODER COMPANY
5595 Walworth • Cleveland, Ohio

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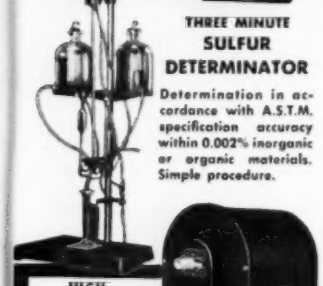
SLITTING AND
TUBE MILL MACHINERY

CARBON and SULFUR ANALYSIS with *Speed! Ease! Accuracy!*

TWO MINUTE CARBON DETERMINATOR
High degree of accuracy assured by: fan cooling gases, leveling to meniscus line, automatically maintaining atmospheric pressure, wide selection of carbon percentage scales. Accurate within 0.002% on low range Burette.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Determination in accordance with A.S.T.M. specification accuracy within 0.002% inorganic or organic materials. Simple procedure.

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WHAT'S NEW

IN MANUFACTURERS' LITERATURE

491. Abrasive Wear

Six-page bulletin, "How to Reduce Abrasive Wear with Thermalloy HC-250", describes the physical properties of the thermalloy HC-250 and lists the many uses and advantages of this exceptionally abrasive-resistant metal. *Electro Alloys Div.*

492. Aircraft Steels

New 68-page booklet on Aircraft Steels, including a digest of many of the Air Force – Navy Federal and AMS specifications pertaining to steel, plus the nearest corresponding AISI analyses. *Jos. T. Ryerson & Son, Inc.*

493. Alloy Brazing

New bulletin 20 covers silver alloy brazing with Easy-Flo and Silfos. Tells where and how to use these alloys to the best advantage. Shows many interesting applications; describes fast brazing techniques. *Handy & Harman.*

494. Alloy Steels

New 16-page, pocket-size booklet entitled "Republic Alloy Steels and How to Get the Most Out of Them" contains seven case histories selected from widely varied fields to demonstrate the versatility of alloy steels. *Republic Steel Corp.*

495. Alloys, Fabricated

Catalog available showing cost-cutting fabricated heat treating equipment for higher payloads and better quality. *Kolock, Inc.*

496. Alloys, Nickel

Hastelloy nickel-base alloys are available for fabricating corrosion-resistant screen, cloth and baskets. Also for metal spraying many types of automatic welding and hardfacing. Booklet, "Hastelloy Nickel-Base Alloys", gives full details. *Haynes Stellite Co.*

497. Aluminum Castings

New 4-page, two-color folder describing the facilities and methods for producing aluminum castings. *Aluminum Industries, Inc.*

498. Aluminum Coating

Reprints now available on Douty-Spruance article, describing protection of aluminum alloys by amorphous phosphate coatings which also provide good surface for paint adhesion. *American Chemical Paint Co.*

499. Aluminum Forgings

To help you in designing for aluminum forgings, a new book is offered, covering relation of forging design to die sinking and relation of forging design to the manufacturing process. Also a section on metallurgy gives all commercial alloy compositions, physical properties and tolerances. *Aluminum Co. of America.*

500. Aluminum Welding

New control system that extends electrode life for spot welding aluminum, fully described in "Technical Advisor No. 15". *Reynolds Metals Co.*

501. Beryllium Copper

Helpful engineering information contained in new monthly series of Beryllium copper technical bulletins. *Beryllium Corp.*

502. Bimetal Elements

64-page catalog written especially to help the design and product engineer select the type and size of thermostatic bimetal element best suited to his temperature-responsive device. *W. M. Chace Co.*

503. Blast Cleaning

Full information available on latest developments in blast cleaning and dust control equipment. *Pangborn Corp.*

504. Brazing

Ajax salt bath brazing process is fully described in bulletin 124. Shows how it is possible to substitute brass for copper and develop joints of adequate strength for most steel assemblies by this brazing method. *Ajax Electric Co.*

505. Brazing Alloys

Standard pricing schedule and torch brazing instructions for silver brazing alloys listed in 4-page leaflet. *American Platinum Works.*

506. Carburizing

Interesting Char booklet tells how activated particles of Char are coated with a heavy shell of carbon, adding to mechanical strength and providing a protective coating. *Char Products Co.*

507. Castings

Bulletin FC-350 outlines the many advantages of improved Fahrite corrosion-resistant castings. *Ohio Steel Foundry Co.*

508. Castings, Alloy

New reference chart gives detailed information on analyses, properties and applications with comparative designations for stainless, corrosion and heat-resistant alloy castings. *Cooper Alloy Foundry Co.*

509. Coatings, Metal

Explanations of high-vacuum evaporation of metals and other solids set forth in detail in new 12-page booklet, "Vaporized Metal-Coatings by High Vacuum". *Distillation Products, Inc.*

510. Contour Projector

New descriptive booklet available on the Kodak Contour Projector, Model 2, for magnifying dimensions, shapes and surfaces in production or toolmaking. Liberal illustrations show how the projector can explore and measure deep recesses in one continuous operation at high magnification. *Eastman Kodak Co.*

511. Copper Alloys

Bulletin B-39 describes Formbrite copper-base alloys, specially processed with superfine grain and hard surface for cold-working of brass in sheet, strip or wire. *American Brass Co.*

512. Copper Alloy Tubes

An extensively illustrated 32-page brochure, "Life Extension for Condenser Tubes", deals with causes of corrosion and means of combating them, as well as choice of materials for condenser tubes. *Revere Copper & Brass, Inc.*

513. Cutting Oil

New booklet available on "Gulf Periodic Consultation Service" provides practical help on your operating and maintenance problems. *Gulf Oil Corp.*

514. Dynamic Micrometer

New literature on an electro-mechanical instrument for measuring displacement, vibration or movement of a ferrous body to within 0.0001 inch. *Electro Products Labs., Inc.*

515. Electrodes

New 12-page booklet, "The ABC's of Welding High Tensile Steels", guides buyers and users of low-alloy, low-hydrogen electrodes. *Arcos Corp.*

516. Finishes

New "Black Book" gives full details on Black Magic finishes for steel, iron, zinc, cadmium, copper and its alloys. *Mitchell-Bradford Chemical Co.*

517. Forging

Information available on designing and construction of forging and heat treating equipment for the production of all types of armament. *Loftus Engineering Corp.*

518. Furnace

Bulletin SC-147 describes new rotary retort-controlled atmosphere furnace for fully automatic high production heat treatments including gas carburizing, dry cyaniding, homogeneous carburizing and cleaning hardening. Also equipped with internal screw-thread for smooth, even heating of small metal parts. *Surface Combustion Corp.*

519. Furnace

Descriptive bulletin available on increased production by means of the Eclipse Rotair air draw furnace. *Eclipse Fuel Engineering Co.*

520. Furnace Controls

Information available on Speedomax potentiometer instruments for simple, economical and dependable temperature control. *Leeds & Northrup Co.*

521. Furnace Controls

New 28-page condensed catalog 51-1 on furnace and oven controls lists prices and illustrates variety of instruments such as temperature controllers, recorders and indicators, control valves, etc. *Minneapolis-Honeywell, Industrial Div.*

522. Furnaces

High temperature furnaces for temperatures up to 2000°F are described in leaflet. *Carl-Mayer Corp.*

523. Furnaces

New bulletin 84P describes eight sizes in gas or electric models as well as complete line of conveyorized and batch or pot-type furnaces. *Despatch Oven Co.*

524. Furnaces

Complete "Buzzer" catalog available describing Buzzer high speed gas furnaces designed primarily for heat treating high carbon and alloy steels and also atmospheric pot hardening furnaces for salt, cyanide and lead hardening. *Charles A. Hones, Inc.*

525. Furnaces

Bulletin HD-850 describes new Shaker Hearth furnace used for bright carburizing, bright dry cyaniding or bright hardening of small parts in processing up to 150 lbs. per hour. *Hevi Duty Electric Co*

526. Furnaces, Industrial

6-page folder describes 18 typical installations of gas-fired, oil-fired and electric furnaces of various types, complete with specially designed equipment for bright annealing, scale-free hardening, carbon restoration, carburizing and production heat treatment. *Electric Furnace Co.*

527. Furnaces, Industrial

For dependably efficient controlled atmosp work, send for bulletin 200 on AGF big furna *American Gas Furnace Co.*

528. Furnaces, Melting

Catalog on Heroult gantry-type electric mel furnace with patented roof-ring to assure spe and simple bricking and eliminate skew sha *American Bridge Co.*

529. Hardness Testers

Bulletin DH-114 contains full information Tukon hardness testers for use in research industrial testing of metallic and nonmet materials. Also included is bulletin DH-7, gi experiences in various fields. *Wilson Mechar Instrument Co.*

530. Heating for Brazing and Annealing

8-page illustrated bulletin on high speed hea equipment for brazing, flame annealing, fl hardening, selective heating, and heating for fo ing. *Gas Appliance Service, Inc.*

531. Heating Elements, Electric

Bulletin H gives detailed information on AT-t nonmetallic electric heating elements, includ tables for a wide variety of sizes available. *Gl Div., Carborundum Co.*

532. Heat-Resistant Casting

New reference chart gives detailed informat on analyses, properties and applications, v comparative designations for stainless, corro and heat-resistant alloy castings. *Cooper A Foundry Co.*

533. Heat Treating

Ipsenlab periodic sheets show case histories bright hardening, annealing and carburizing. *I Industries, Inc.*

534. Heat Treating

Bulletin 96 tells how Niagara Aero heat excha ets provide better heat treating by evapora cooling that controls temperatures, protects pl cal properties, and saves on water and pi equipment. *Niagara Blower Co.*

535. Heat Treating Carriers

Complete line of standard carburizing car that will handle odd-shaped parts of every through carburizing and quenching to finish Write for full infotmation. *Pressed Steel Co.*

536. Heat Treating Furnace

Information available on mechanized batch-t controlled atmosphere furnaces for gas cyanid gas carburizing, clean hardening or carbon toration work. *Dow Furnace Co.*

537. Heat Treating Furnace

Illustrated literature describes newest devel ments in gas and electric heat treating furna *Westinghouse Electric Corp.*

538. Heat Treating Small Parts

Bulletin 78 describes time-saving features electric heat treating furnaces specially desig for small parts. *Cooley Electric Mfg. Co.*

539. High-Temperature Testing

For precise hi-temperature testing, send illustrated technical folder on Marshall equipm *Marshall Products Co.*

540. Hydraulic Pump

Folder on a new constant-displacement operated pump for use on hydraulic pres die-sinking and die-casting machines, and mach tools. *American Engineering Co.*

541. Immersion Heating

Bulletin 1E-11 gives complete details on h new immersion pots save time and money melting soft metals. High thermal efficiency both large and small units provides rapid h recovery in one-third the time. *C. M. Ke Mfg. Co.*

542. Induction Heating

Bulletin 1440 furnishes full details on "Checklite" system for safety control through use of oversized components built into every u for longer service life and uninterrupted prod tion. *Lindberg Engineering Co.*

543. Induction Melting

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544. Iron, Ductile

New list of publications available on advanta and properties of ductile iron, along with spe applications and 100 authorized foundry sour new producing it. *International Nickel Co.*

545. Machine Design

Fundamentals of producing low-cost mach parts—design, material and treatment—are cussed in 72-page "Three Keys to Satisfactio *Climax Molybdenum Co.*

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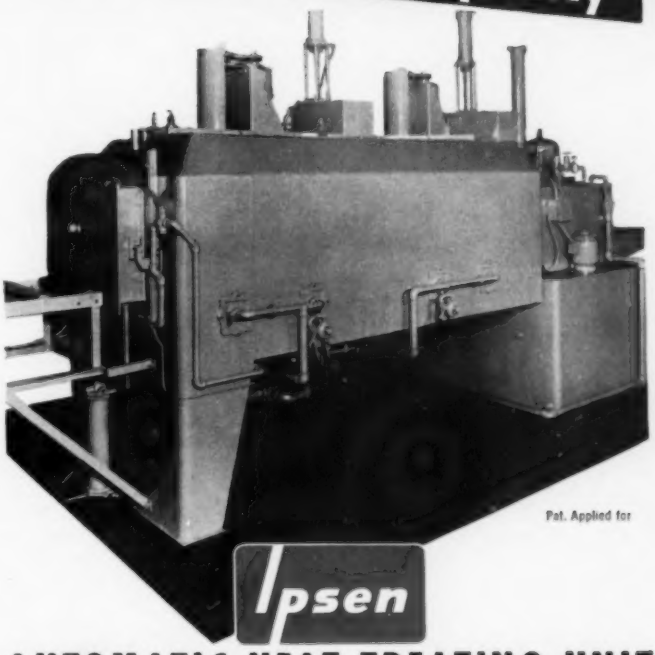

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● To meet the demand for a larger capacity furnace our standard T-250 with all its features, has an additional heating chamber, boosting the capacity to over 600 lbs. per hour. Individual control of each heating zone gives a wide flexibility. Typical use of these units is for DEEP CASE carburizing. Heating in first zone at 1750° F. and lowering to 1575° F. in the second zone for quenching. Work is automatically loaded, transferred and quenched.

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High degree of accuracy assured by: fan cooling gases, leveling to meniscus line, automatically maintaining atmospheric pressure, wide selection of carbon percentage scales. Accurate within 0.002% on low range Buretts.

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Sturdy construction with HIGHEST QUALITY insulation.

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WHAT'S NEW

IN MANUFACTURERS' LITERAT

546. Magnesium Die Castings

Revealing book, "How Magnesium Pays", gives case studies of the economical uses of magnesium in a wide range of products. *Dow Chemical Co.*

547. Metal Cleaning

Information on new cleaning process that uses emulsion cleaners, based on petroleum and addition agent 230. This two-phase bath provides unique cleaning in conjunction with a thin displacement film that removes foreign particles. *Northwest Chemical Co.*

548. Metal Cleaning

Bulletin 213 gives full details, specifications and actual performance on faster blast cleaning with Rotoblast barrels. *Pangborn Corp.*

549. Metal Cutting

New 64-page catalog No. 28 gives prices and describes complete line of rotary files, burs, metal-working saws and other products. *Martindale Electric Co.*

550. Metal-Forming Lubrication

New bulletin 426-B describes how colloidal graphite can solve your lubrication problems in metal-forming operations at temperatures from below zero up to 5000°F. *Acheson Colloids Corp.*

551. Metal Hydrides

4-page folder on various hydrides of metals. Describes the use of these compounds in alloying, powder metallurgy and other metallurgical and chemical applications. *Metal Hydrides, Inc.*

552. Metallizing Process

New 8-page bulletin "Mogul Cast-Seal Impregnating Process" fully explains the equipment used in this process for positive, low-cost method of eliminating casting porosity. *Metallizing Co. of America.*

553. Metal-Treating Ammonia

Bulletins available on "Ammonia Installations for Metal Treating", "Effective Use of Dissociated Ammonia", "Carbonitriding of Steel" and "Nitriding Process". *Armour Ammonia Div.*

554. Microcasting

New color-illustrated folder, "Microcast Case Histories", describes microcasting applications for both industrial and defense requirements. *Austenal Laboratories, Inc.*

555. Micrographic Equipment

Six-page bulletin on a universal camera microscope giving plate magnifications from 4 to 3000 X. Full details on optics and accessories included. *Opplem Co.*

556. Microscopes

New stereoscopic wide-field microscopes invaluable in preparation of polished metal specimens, study of fractures, porosity, and macro-etched specimens fully described in catalog D-15. *Bausch & Lomb Optical Co.*

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557. Midget Die Casting Machine

Illustrated folder describes new Kux Model K, small die casting machine, available in horizontal or vertical center shot models and capable of producing die castings weighing up to 1½ pounds in zinc under high injection pressures. *Kux Machine Co.*

558. Nonferrous Castings

Colorful folder No. 542 illustrates a number of centrifugal castings with diameters ranging from 3 to 54 inches and in lengths up to 327 inches. Included are specifications for large number of nonferrous compositions showing alloy designations and physical properties. *Sandusky Foundry & Machine Co.*

559. Nonferrous Castings

16-page anniversary book, "The Lavingot", Vol. 6, No. 3, furnishes an interesting picture story of 50 years of outstanding contributions to the metal industry. Also furnishes tabular information on nonferrous casting alloys and helpful notes on foundry practice. *R. Lavin & Sons, Inc.*

560. Oil Quenching

New folder available on oil quenching without distortion, using hot oil at temperatures up to 350°F. without undue thickening or oxidation. *E. F. Houghton & Co.*

561. Oils, Cutting

Facts on more efficient and economical plant operation through use of right lubricants described in "Metal Cutting Fluids" booklet. *Cities Service Oil Co.*

562. Oils, Cutting

Valuable information available on defense work problems in tolerances and finishes required by Armed Services on high temperature alloys and super stainless steels. *D. A. Stuart Oil Co.*

563. Ovens

Bulletin 4-T describes complete line of batch and conveyor-type ovens to meet every requirement in ferrous and nonferrous heat treating and also light alloys. *Young Brothers Co.*

564. Ovens, Furnaces

18 standard sizes of furnaces and ovens, oil, gas or electric; in batch or conveyor type for rapid, uniform heating in controlled temperature and atmosphere, described in bulletin 413. *W. S. Rockwell Co.*

565. Piping and Tubing

New 68-page book is a practical treatise on pipe and tube making, answering many pertinent questions on tube mill operations and production. *Yoder Co.*

566. Polishing and Buffing

Bulletin entitled "Acme Straightline Automatic Polishing and Buffing Machines" illustrates and describes a machine for every type of polishing and buffing job. *Acme Mfg. Co.*

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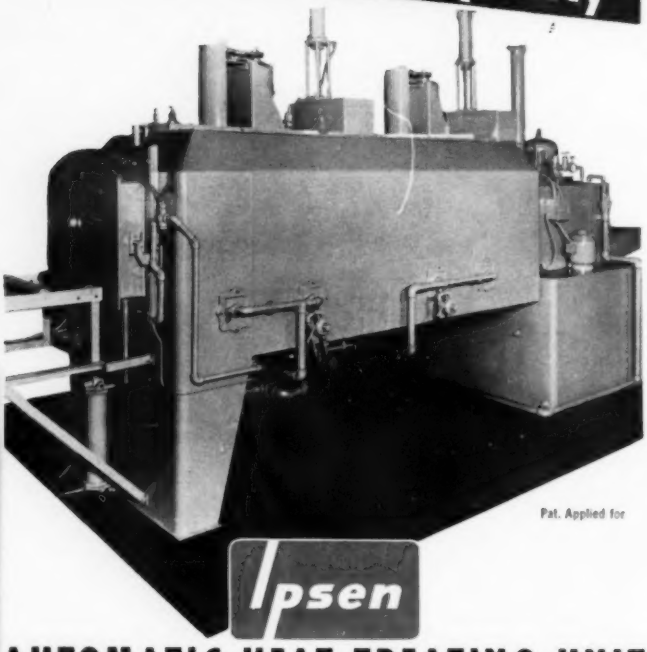

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2 Zone Control...Ideally Suited for

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567. Potentiometer, Portable

Bulletins 270 and 270-A describe portable potentiometers in a selection of ranges up to 1.6 volts. *Rubicon Co.*

568. Pressure Blasting

4-page illustrated folder describing line of newly developed compact wet-blasting units with no moving parts, designed for high-production deburring, descaling, stock removal and general surface finishing. *Cro-Plate Co.*

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571. Quenching Oil

New technical bulletin F8 describes triple-action quenching oil. Accelerators provide deeper hardening and reduced distortion. *Park Chemical Co*

572. Reclaiming Process

Bulletin 330-D furnishes complete data on Engelhard Reclaiming Process, showing how on one 30" long platinum thermocouple it saved 53% compared with cost of new unit. *Chas. Engelhard, Inc.*

573. Recorders

Bulletin C2-2 describes Capacilog line of electronically operated strip chart recorders. Also lists model numbers and specifications and explains how Direct Deflection, Wheatstone Bridge Circuit and Pneumatic Control types of systems are applied to Capacilogs. *Wheelco Instruments Co.*

574. Refractories

Bulletin 202 outlines many advantages of Zircon refractories, including resistance to "wetting" by pure aluminum, elimination of silicon pick-up and easy cleaning when used in aluminum remelting furnaces. *Chas. Taylor Sons Co.*

575. Refractories

40-page booklet, "Super Refractories for Heat Treatment Furnaces", gives recommendations for many specific types of furnaces. *Carborundum Co.*

576. Refractories

New 24-page bulletin, Form 458, tells the whole story about building electric furnaces for laboratory use. *Norton Co.*

577. Refractory Brick

New 4-page illustrated folder, "JM-3000 Insulating Fire Brick", presents economic advantages, industrial applications and refractory properties of this product, for sustained use at 3000°F. *Johns-Manville.*

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578. Refractory Concrete

Revised bulletin entitled "Lumnite Refractory Concrete" discusses latest available information on refractories and heat-resistant concrete. *Lumnite Div., Universal Atlas Cement Co.*

579. Salt Baths

Valuable technical information available on heat treatment and molten salt bath operations. *E. I. duPont de Nemours & Co.*

580. Saws

Catalog 49 describes complete line of metal-cutting saws, covering 35 models in ten basic types, including fast, automatic production saw, hydraulic hacksaws, and widely used small shop saws. *Armstrong-Blum Mfg. Co.*

581. Specimen Mounter

Bulletin 5-713 gives full details on precision semi-automatic specimen mounter. A self-contained unit with air-cylinder automatically maintains pressure on specimen mount, relieves operator. *Precision Scientific Co.*

582. Specimen Polishing with Diamond Compound

4-page folder describes the advantages of diamond abrasives for polishing metallurgical specimens. Diamet-Hyprez is offered in three different particle sizes, all in 5-gram and 18-gram gun applicators. *Buehler, Ltd.*

583. Spectrophotometer

Bulletin B-211 illustrates junior-size spectrophotometer for identifying and measuring solution constituents in analytical or production laboratories. *Harshaw Chemical Co.*

584. Spring Wire

Detailed information on Pittsburgh oil tempered spring wire to help solve coiling, knotting, forming and twisting operation problems. *Pittsburgh Steel Co.*

585. Steel, Alloy

New 4-page bulletin, "Prestem. The Hot Working Die Steel for Forging Presses and Upsetters", describes this new alloy steel, of the low carbon-nickel, molybdenum type and provides charts showing how surface hardness of Prestem increases with temperature rise up to 1050°F. *Heppenstall Co.*

586. Steel Selector

Handy, clearly printed, easy-to-use tool steel selector will be furnished on request. *Crucible Steel Co. of America.*

587. Steels, High Speed

New booklet on Electrite Double-Six will assist new and old users of these Desegatized molybdenum high speed steels with complete and up-to-date information on analyses, forging, hardening, tempering, testing and recommended uses. *Latrobe Electric Steel Co.*

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588. Steels, Low Alloy

You can have one-third more production through the use of Hi-Steel, which has nearly twice the working strength of ordinary steels plus the ability to stand up under impact loads. Send for booklet. *Inland Steel Co.*

589. Stainless Steel Hardening

16-page illustrated booklet giving test results and showing advantages and applications of stainless steel parts hardened by the Scottsonizing process. *C. U. Scott & Son, Inc.*

590. Steels, Stainless

Weekly lists with analyses of all plates in stock will keep you regularly informed on latest data. *G. O. Carlson, Inc.*

591. Sulfur and Carbon Analysis

Descriptive literature available on carbon and sulfur determinators for economical analysis with speed and accuracy. *Harry W. Dietert Co.*

592. Temperature Control

Information available on new Alnor temperature controller, furnishing low-cost, positive temperature control to heat-treating furnaces, bake-ovens of any heating device electrically heated or fuel fired. *Illinois Testing Labs.*

593. Tempilstiks°

"Basic Guide to Ferrous Metallurgy", a plastic laminated wall chart in color, furnished on request. *Claud S. Gordon Co.*

594. Testing

New 28-page catalog on screw power universal testing machines and accessories includes illustrations and details of construction and specifications. Also information on special tools for different tests. *American Machine & Metals, Inc.*

595. Thermocouples

New 56-page buyers' guide and users' manual lists wide variety of thermocouple assemblies, pyrometer tubes, thermocouple wire and extension wire. Also contains many new facts on correct selection and application of pyrometer supplies. *Bristol Co.*

596. Thermocouples

Chart showing the resistance tables, applications, calibration symbols, conductors, polarity and color codes of thermocouple and extension wires. *Thermo Electric Co.*

597. Tool Steel

New booklet, "How to Get Better Tool and Die Performance", furnishes full description of the matched set method for selecting the right tool steel for trouble-free production. *Carpenter Steel Co.*

598. Tubing

For full information on analyses available, production limits, commercial tolerances, temper designations and product descriptions of Seamless and Weldrawn tubing, send for bulletin 32. *Superior Tube Co.*

599. Tubing, Alloy

New catalog contains complete list of products and prices in warehouse stock of alloy steel tubing. *Timken Roller Bearing Co.*

600. Vacuum Fusion Analyzer

Further information available on Type 09-1240, a new packaged unit vacuum fusion gas analyzer, used to determine the content of oxygen, nitrogen and hydrogen in metals. *National Research Corp.*

601. Vapor Degreasing

New 21-page handbook answers most generally asked questions on what vapor degreasing is and where it can be applied. Also carries photographs of various units and useful data charts. *Phillips Mfg. Co.*

602. Vapor Degreasing

Pamphlet on properties and use of trichlorethylene as a solvent for vapor degreasing of metal parts. *Niagara Alkali Co.*

603. Vibration Tester

Descriptive literature on a compact electro-mechanical device measuring torsional and flexural characteristics of metals and determining modulus of elasticity. *Electro Products Labs.*

604. Welding, Copper

18-page article, "Aircomatic Welding of Copper-Base Alloys", encompasses general investigation into the weldability of several copper-base alloys with the recently developed inert-gas-shielded metal-arc welding process. *Air Reduction Sales Co.*

605. Welding Electrodes

"Arc Welding Stainless Steel Without Columbium", title of a new booklet giving complete details on Arcaloy 308 ELC and 316 ELC for welding stainless types 321 and 316 without appreciable carbide precipitation. *Alloy Rods Co.*

606. Welding and Cutting

Information available on oxygen-cutting and powder-cutting with Oxweld equipment to rapidly convert any steel or cast iron section into good, usable scrap. *Linde Air Products Co.*

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Bulletin 330-D furnishes complete data on Engelhard Reclaiming Process, showing how on one 30" long platinum thermocouple it saved 53% compared with cost of new unit. *Chas. Engelhard, Inc.*

573. Recorders

Bulletin C2-2 describes Capacilog line of electronically operated strip chart recorders. Also lists model numbers and specifications and explains how Direct Deflection, Wheatstone Bridge Circuit and Pneumatic Control types of systems are applied to Capacilogs. *Wheelco Instruments Co.*

574. Refractories

Bulletin 202 outlines many advantages of Zircon refractories, including resistance to "wetting" by pure aluminum, elimination of silicon pick-up and easy cleaning when used in aluminum remelting furnaces. *Chas. Taylor Sons Co.*

575. Refractories

40-page booklet, "Super Refractories for Heat Treatment Furnaces", gives recommendations for many specific types of furnaces. *Carborundum Co.*

576. Refractories

New 24-page bulletin, Form 458, tells the whole story about building electric furnaces for laboratory use. *Norton Co.*

577. Refractory Brick

New 4-page illustrated folder, "JM-3000 Insulating Fire Brick", presents economic advantages, industrial applications and refractory properties of this product, for sustained use at 3000°F. *Johns-Manville.*

578. Refractory Concrete

Revised bulletin entitled "Lumnite Refractory Concrete" discusses latest available information on refractories and heat-resistant concrete. *Lumnite Div., Universal Atlas Cement Co.*

579. Salt Baths

Valuable technical information available on heat treatment and molten salt bath operations. *E. I. duPont de Nemours & Co.*

580. Saws

Catalog 49 describes complete line of metal-cutting saws, covering 35 models in ten basic types, including fast, automatic production saw, hydraulic hacksaws, and widely used small shop saws. *Armstrong-Blum Mfg. Co.*

581. Specimen Mounter

Bulletin 3-713 gives full details on precision semi-automatic specimen mounter. A self-contained unit with air-cylinder automatically maintains pressure on specimen mount, relieves operator. *Precision Scientific Co.*

582. Specimen Polishing with Diamond Compound

4-page folder describes the advantages of diamond abrasives for polishing metallurgical specimens. Diamet-Hyprez is offered in three different particle sizes, all in 5-gram and 18-gram gun applicators. *Buehler, Ltd.*

583. Spectrophotometer

Bulletin B-211 illustrates junior-size spectrophotometer for identifying and measuring solution constituents in analytical or production laboratories. *Harshaw Chemical Co.*

584. Spring Wire

Detailed information on Pittsburgh oil tempered spring wire to help solve coiling, knotting, forming and twisting operation problems. *Pittsburgh Steel Co.*

585. Steel, Alloy

New 4-page bulletin, "Prestem, The Hot Working Die Steel for Forging Presses and Upsetters", describes this new alloy steel, of the low carbon-nickel, molybdenum type and provides charts showing how surface hardness of Prestem increases with temperature rise up to 1050°F. *Heppenstall Co.*

586. Steel Selector

Handy, clearly printed, easy-to-use tool steel selector will be furnished on request. *Crucible Steel Co. of America.*

587. Steels, High Speed

New booklet on Electrite Double-Six will assist new and old users of these Desegatized molybdenum high speed steels with complete and up-to-date information on analyses, forging, hardening, tempering, testing and recommended uses. *Latrobe Electric Steel Co.*

588. Steels, Low Alloy

You can have one-third more production through the use of Hi-Steel, which has nearly twice the working strength of ordinary steels plus the ability to stand up under impact loads. Send for booklet. *Inland Steel Co.*

589. Stainless Steel Hardening

16-page illustrated booklet giving test results and showing advantages and applications of stainless steel parts hardened by the Scottsonizing process. *C. U. Scott & Son, Inc.*

590. Steels, Stainless

Weekly lists with analyses of all plates in stock will keep you regularly informed on latest data. *G. O. Carlson, Inc.*

591. Sulfur and Carbon Analysis

Descriptive literature available on carbon and sulfur determinators for economical analysis with speed and accuracy. *Harry W. Dietert Co.*

592. Temperature Control

Information available on new Alnor temperature controller, furnishing low-cost, positive temperature control to heat-treating furnaces, bake-ovens of any heating device electrically heated or fuel fired. *Illinois Testing Labs.*

593. Tempilstiks°

"Basic Guide to Ferrous Metallurgy", a plastic laminated wall chart in color, furnished on request. *Claud S. Gordon Co.*

594. Testing

New 28-page catalog on screw power universal testing machines and accessories includes illustrations and details of construction and specifications. Also information on special tools for different tests. *American Machine & Metals, Inc.*

595. Thermocouples

New 56-page buyers' guide and users' manual lists wide variety of thermocouple assemblies, pyrometer tubes, thermocouple wire and extension wire. Also contains many new facts on correct selection and application of pyrometer supplies. *Bristol Co.*

596. Thermocouples

Chart showing the resistance tables, applications, calibration symbols, conductors, polarity and color codes of thermocouple and extension wires. *Thermo Electric Co.*

597. Tool Steel

New booklet, "How to Get Better Tool and Die Performance", furnishes full description of the matched set method for selecting the right tool steel for trouble-free production. *Carpenter Steel Co.*

598. Tubing

For full information on analyses available, production limits, commercial tolerances, temper designations and product descriptions of Seamless and Weldrawn tubing, send for bulletin 32. *Superior Tube Co.*

599. Tubing, Alloy

New catalog contains complete list of products and prices in warehouse stock of alloy steel tubing. *Timken Roller Bearing Co.*

600. Vacuum Fusion Analyzer

Further information available on Type 09-1240, a new packaged unit vacuum fusion gas analyzer, used to determine the content of oxygen, nitrogen and hydrogen in metals. *National Research Corp.*

601. Vapor Degreasing

New 21-page handbook answers most generally asked questions on what vapor degreasing is and where it can be applied. Also carries photographs of various units and useful data charts. *Phillips Mfg. Co.*

602. Vapor Degreasing

Pamphlet on properties and use of trichlorethylene as a solvent for vapor degreasing of metal parts. *Niagara Alkali Co.*

603. Vibration Tester

Descriptive literature on a compact electromechanical device measuring torsional and flexural characteristics of metals and determining modulus of elasticity. *Electro Products Labs.*

604. Welding, Copper

18-page article, "Aircomatic Welding of Copper-Base Alloys", encompasses general investigation into the weldability of several copper-base alloys with the recently developed inert-gas-shielded metal-arc welding process. *Air Reduction Sales Co.*

605. Welding Electrodes

"Arc Welding Stainless Steel Without Columbium", title of a new booklet giving complete details on Arcaloy 308 ELC and 316 ELC for welding stainless types 321 and 316 without appreciable carbide precipitation. *Alloy Rods Co.*

606. Welding and Cutting

Information available on oxygen-cutting and powder-cutting with Oxweld equipment to rapidly convert any steel or cast iron section into good, usable scrap. *Linde Air Products Co.*

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METAL PROGRESS
7301 Euclid Avenue, Cleveland 3, Ohio

June, 1951

478	501	524	547	570	593
479	502	525	548	571	594
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- Generous Sized Cabinets
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- Industrial Type tubes

Conditioned cooling completely eliminates water condensation on high voltage parts — reduces water consumption and pressure requirements — permits the use of this equipment in hard water areas.

Tough... rugged... and above all reliable! Lindberg Induction Heating Units have built a reputation for reliability and ruggedness that equals that of the old-time blacksmith. They are built rugged for heavy production line service—hour after hour—day after day ... far beyond the usual capabilities of Induction Heating Equipment.

For fast, accurate, selective heating—controlled in both depth of penetration and area covered—investigate the Lindberg Induction Heating Units. You will profit from their rugged ability to deliver 24 hour a day operation—day after day. Ask for Bulletin 1440.

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To Furnaces and Workloads

. . . WITH THE
PROTECT-O-VANE
EXCESS TEMPERATURE SAFETY CUT-OFF CONTROLLER

MANY installations, where temperature is a factor in processing, are running the risk of serious damage from excess temperatures resulting from equipment failure. The cost can be considerable . . . expensive furnace repairs . . . a ruined work load . . . loss of valuable production time!

The *Protect-O-Vane* is daily providing inexpensive insurance against loss due to excess temperatures, in many hundreds of industrial plants. It automatically cuts off the power and/or the fuel supply if the safe temperature limit is exceeded. Simultaneously, a warning signal is given by means of a flashing neon light mounted on the front of the instrument . . . and by an audible alarm, if desired.

It Costs So Little to Protect So Much! The *Protect-O-Vane* is most reasonably priced, and gives proved protection against failures which could be so expensive. It can be used with any type of controller, or alone, and is applied to all types of furnaces, ovens and other heating equipment.

Call in your local Honeywell engineer for a discussion of its value in your plant . . . he is as near as your phone.

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- √ Reset must be manual, by means of button on front of case, and is not effective until temperature drops to safe point.
- √ "Fail-Safe" design . . . flashing neon light warns of component failure.
- √ Thermocouple burn-out protection is standard equipment.
- √ Instantaneous action . . . provided by electronic control unit and snap-acting 5 or 30-ampere load relay.
- √ Easily read 6" wide scale in compact 9" wide case . . interchangeable for flush or surface mounting.

For Complete Information Write for Specification Number 113.

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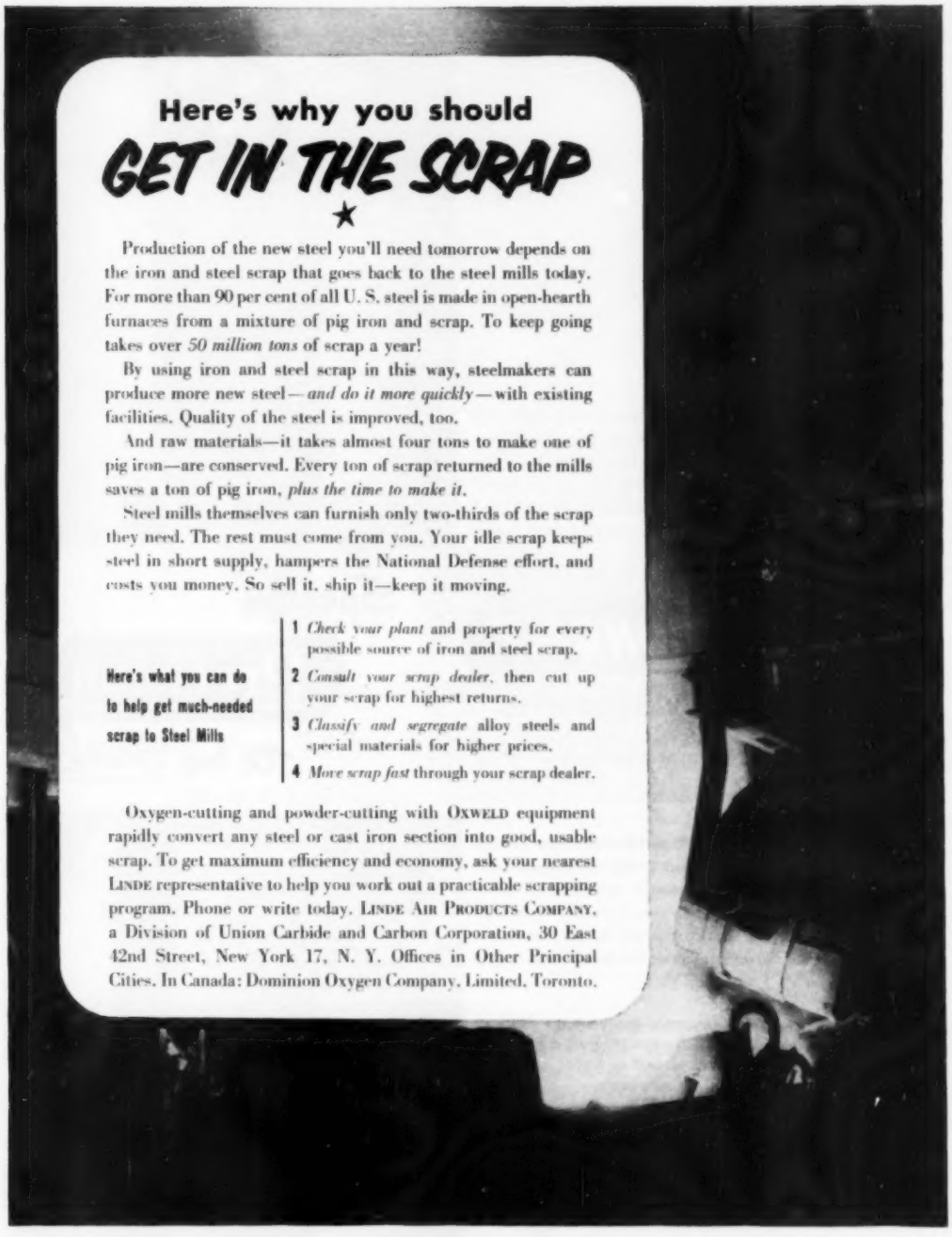

Here's why you should

GET IN THE SCRAP

★

Production of the new steel you'll need tomorrow depends on the iron and steel scrap that goes back to the steel mills today. For more than 90 per cent of all U. S. steel is made in open-hearth furnaces from a mixture of pig iron and scrap. To keep going takes over *50 million tons* of scrap a year!

By using iron and steel scrap in this way, steelmakers can produce more new steel—*and do it more quickly*—with existing facilities. Quality of the steel is improved, too.

And raw materials—it takes almost four tons to make one of pig iron—are conserved. Every ton of scrap returned to the mills saves a ton of pig iron, *plus the time to make it.*

Steel mills themselves can furnish only two-thirds of the scrap they need. The rest must come from you. Your idle scrap keeps steel in short supply, hampers the National Defense effort, and costs you money. So sell it, ship it—keep it moving.

Here's what you can do to help get much-needed scrap to Steel Mills

1 *Check your plant* and property for every possible source of iron and steel scrap.

2 *Consult your scrap dealer*, then cut up your scrap for highest returns.

3 *Classify and segregate* alloy steels and special materials for higher prices.

4 *Move scrap fast* through your scrap dealer.

Oxygen-cutting and powder-cutting with OXWELD equipment rapidly convert any steel or cast iron section into good, usable scrap. To get maximum efficiency and economy, ask your nearest LINDE representative to help you work out a practicable scrapping program. Phone or write today. LINDE AIR PRODUCTS COMPANY, a Division of Union Carbide and Carbon Corporation, 30 East 42nd Street, New York 17, N. Y. Offices in Other Principal Cities. In Canada: Dominion Oxygen Company, Limited, Toronto.

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Products and Processes for MAKING, CUTTING, JOINING, TREATING, AND FORMING METALS

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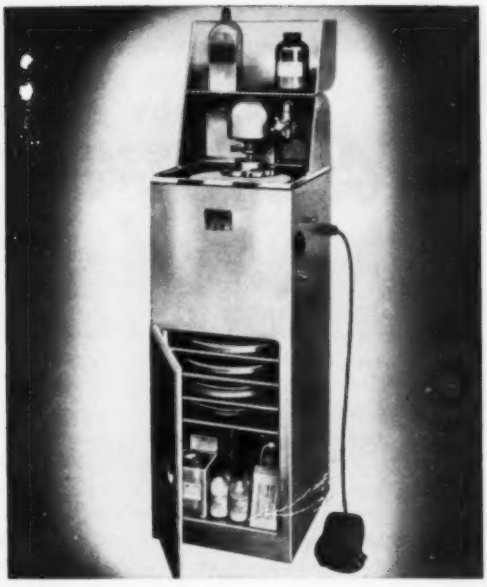

PRECISION Automatic Specimen-Polisher ideally completes 3-step technique (cutting, mounting, polishing) by *shearing*, not buffing or pulling, inclusions. Faster: about 30 minutes for 12 specimens. Uniform: no human variation. Lower cost: less skilled personnel-time, no spoiled specimens. Bulletin 5-513

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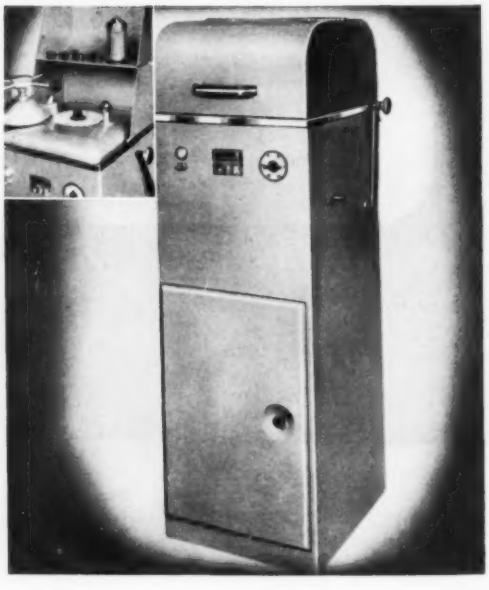
lower cost, more volume—

Specify *Precision to be Sure



PRECISION Semi-Auto. Specimen Mounter for the second step in our noted 3-step technique. Self-contained unit with air-cylinder, automatically maintains pressure on specimen mount, relieves operator. Dual thermostatic heat control, pre-set air control, bell curing-timer. Saves space and trouble. Bulletin 5-713

To make your work easier, surer, more economical, replace or implement your present facilities with selections from some 3,000 Precision products. "Utility" items as well as highly specialized instruments are built beyond duty requirements.

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Wherever accurate temperature measurement is important to the finished quality of work . . . in laboratory analysis or on heat treat operations . . . you'll find that nearly always the pyrometers in use are calibrated for Hoskins CHROMEL-ALUMEL thermocouple alloys.

And for good reasons, too. Because CHROMEL-ALUMEL thermocouple wire carries a positive accuracy guarantee . . . ±5° F. at temperatures up to 660° F., and ±¾% from 660° F. and over. It's highly responsive to temperature fluctuations . . . so resistant to oxidation that you need not pack the protection tube . . . and it maintains its fine accuracy over longer periods of time than any other base metal thermocouple material. So if you're responsible for accurate temperature measurement, better check your pyrometers to make sure they're properly calibrated, then specify couples by name . . . CHROMEL-ALUMEL thermocouples. Available through your instrument manufacturer or pyrometer service company.

PS—And while you're at it . . . complete your chain of accuracy with CHROMEL-ALUMEL "extension" leads. For, by using wires of identical compositions for both couples and leads, you eliminate all possibility of "cold-end" errors.

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Performance of railroad journal bearings, under heavy load applications at relatively low speeds, can not be anticipated by the usual physical tests of tensile strength, elongation, etc. Since it is impossible to maintain a perfect oil film between the rotating journal and bearing, the behavior of bearing metals under momentary *metal-to-metal* contact becomes a major distinguishing characteristic.

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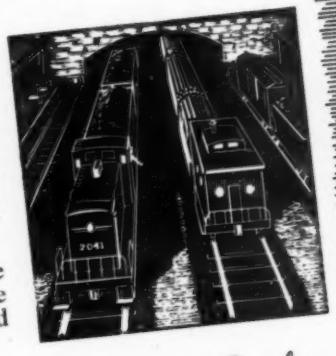

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REPRESENTATIVES IN PRINCIPAL CITIES

MAGNESIUM

and the problem of

WEIGHT

in your product

From designer's board to customer's hands, weight in your product may be expensive. Weight enters into the cost of the raw material. Weight determines production methods and machinery requirements. It enters into the cost of labor and the cost of transportation. And in many products, extra weight is a costly penalty in sales results. Weight, wherever it is found, costs money.

Now, consider magnesium. Here is the world's lightest structural metal. Its weight is nearly 75% less than that of steel . . . 33% less than aluminum. Wherever design is based on weight limitations, this lightness permits the use of thicker, more rigid sections without a weight penalty. In thousands of applications, magnesium has permitted better design, better performance, more payload, and at the same time decreased costly weight.

In redesigning your product for tomorrow's market, plan with magnesium, the world's lightest structural metal, a standard material wherever light weight is important.

This Little "Pig" Was Drafted . . .

Today, magnesium like many other metals, is a tremendously important part of our defense effort, particularly where light weight is a specification in design. For instance, a B-36 bomber uses nearly 30,000 pounds of magnesium. But tomorrow, magnesium promises new horizons in the field of metal supply. *The seas, at our own shores, can provide 100,000,000 tons of magnesium per year for a million years without significantly reducing the supply!*

Magnesium Division

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TEN TIMES THE LIFE AND STILL GOING STRONG!

Ni-Hard† Pipe Proves Superiority in Resisting Abrasive Action

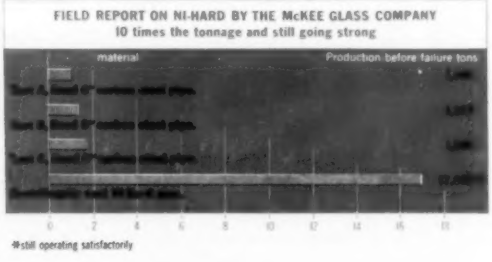
If your problem is abrasion, you'll be interested in this case history of Metal Mold centrifugally cast Ni-Hard pipe in action.

The McKee Glass Company, one of the nation's leading producers of molded glass for household and industry, uses a pneumatic conveyor system to handle its glass furnace charges. In this system tons of silica, sand, feldspar, borax, etc., are hurled at tornado-like speeds . . . about 100 miles per hour . . . through vacuum lines from boxcars to storage bins. Broken glass scrap (cullet) is added at the mixers to form a highly abrasive mixture.

Two years ago when the system was installed steel piping and later, lined steel piping was used. The severe abrasive action coupled with serious discoloration of the glass led to the search for a better conveying material. As a result, Metal Mold centrifugally cast plain end Ni-Hard pipe with a Brinell hardness of 600-650 was installed in the line's most abrasive sections.

The result, as reported by McKee, was more than satisfactory. Contamination was reduced 80%. Ni-Hard resisted abrasion much more effectively, as shown by the chart below . . . thus far, in fact, has carried *ten times the tonnage and the line is still going strong!*

Today, the McKee Glass Company uses Ni-Hard exclusively in its conveying system. Their experience may suggest the answer to *your* abrasion problem.



†Nickel-chromium white cast iron.
Ni-Hard is a registered trade name of
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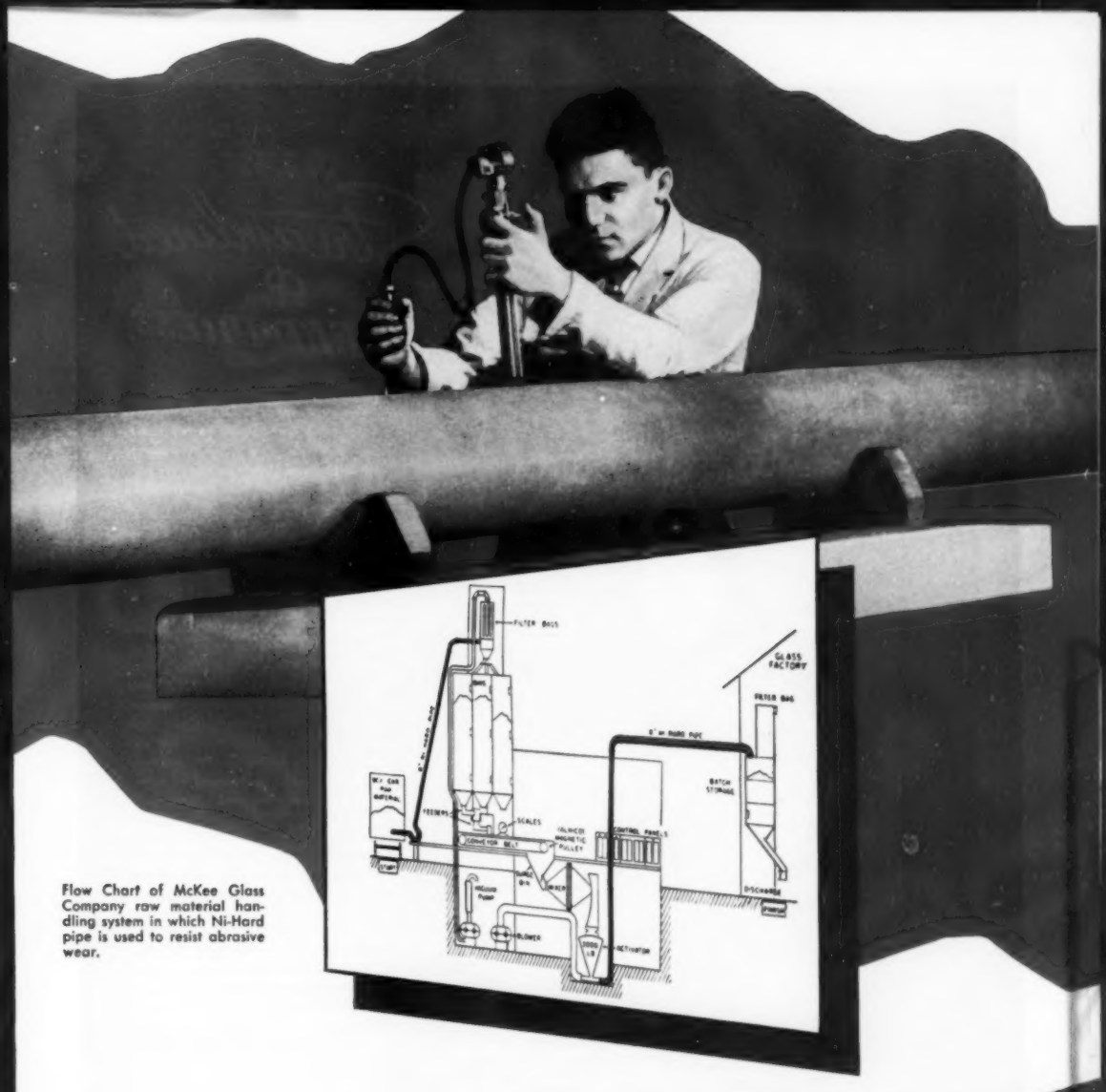
AMERICA'S LARGEST PRODUCER OF CENTRIFUGUALLY



Flow Chart of McKee Glass Company raw material handling system in which Ni-Hard pipe is used to resist abrasive wear.

FOUNDRY CO.

BURLINGTON, N. J.

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TYPES OF METAL CAST

Stainless Steel—All AISI Types, also special low and corrosion resistant analyses.

Alloy Steel—all grades.

Carbon Steel—all grades.

Gray and Alloy Iron—all standard and special analyses, including Ni-Hard and Ni-Resist.

"Dual Metal"—Gray or alloy iron inside steel; gray iron inside chilled iron and tool steel; iron or steel inside stainless; and many other metallurgically bonded two-metal centrifugally cast combinations.

SIZE RANGE

Outside diameter—2½" through 30". Wall Thickness—⅜" to 4". Lengths—Up to 14'.

NEW Streamlined AB SPEED PRESS

The most advanced design in press equipment for speed, convenience, and economy in the production of Bakelite and Transparent Molded Specimen Mounts ever presented to the metallurgist.

A revolutionary feature introduced in this new press is preheated Premolds. The preheat compartment reduces the curing time of thermo-setting molds to one-third of the time usually required. It enables the operator to produce perfect Bakelite Mounts in 2½ to 3½ minutes. All necessary indicators and controls including pressure gauge, pyrometer, thermostats, timer and pilot lights are provided. No experience is required to produce perfect mounts. Automatic ram retraction saves time and effort.

The hinged press head is made with a semi-automatic lock and a hand wheel screw to close the mold securely. Heating blocks are arranged with a magnetic closure to snugly envelop the mold assembly. The interchange of thermostatically controlled heating units of 600 watt capacity is facilitated by convenient supports. Cooling blocks are located in a practical position in front of the press cabinet.

This new speed press is the result of long exacting experiment, with every effort devoted to designing the finest modern specimen press we are able to engineer.

No. 1330 AB Speed Press, complete for 1" mountings $420.00

No. 1330-2 AB Speed Press, complete for 1¼" mountings $440.00

No. 1330-3 AB Speed Press, complete for 1½" mountings $460.00

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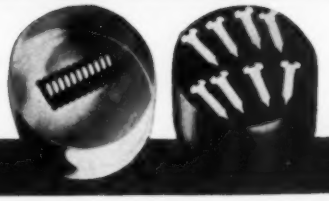

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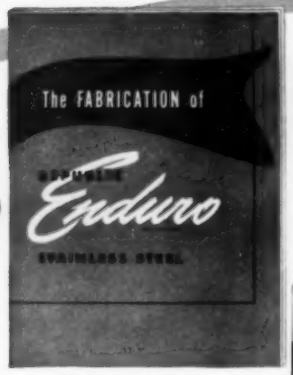
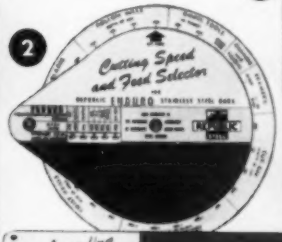
If you use ALLOY or STAINLESS STEELS . . .

Republic offers you these helpful processing aids—without cost or obligation. Send for them today.





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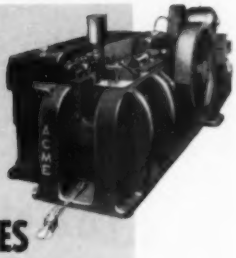
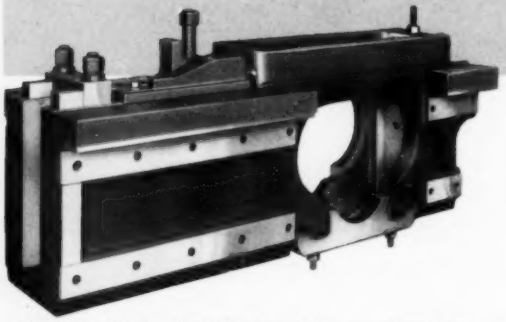
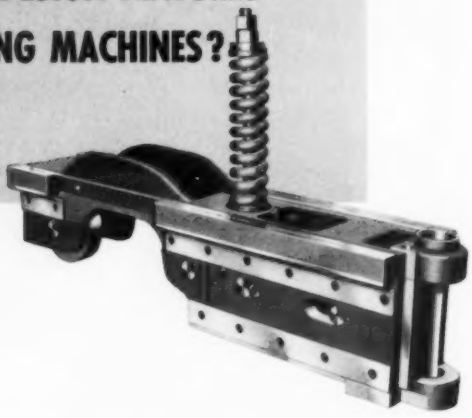


ABOUT THESE THREE ADDITIONAL DESIGN FEATURES EXCLUSIVE WITH ACME XN FORGING MACHINES?





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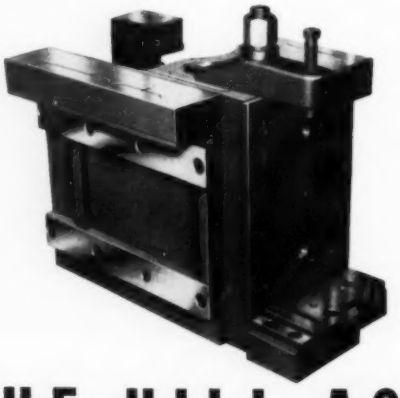

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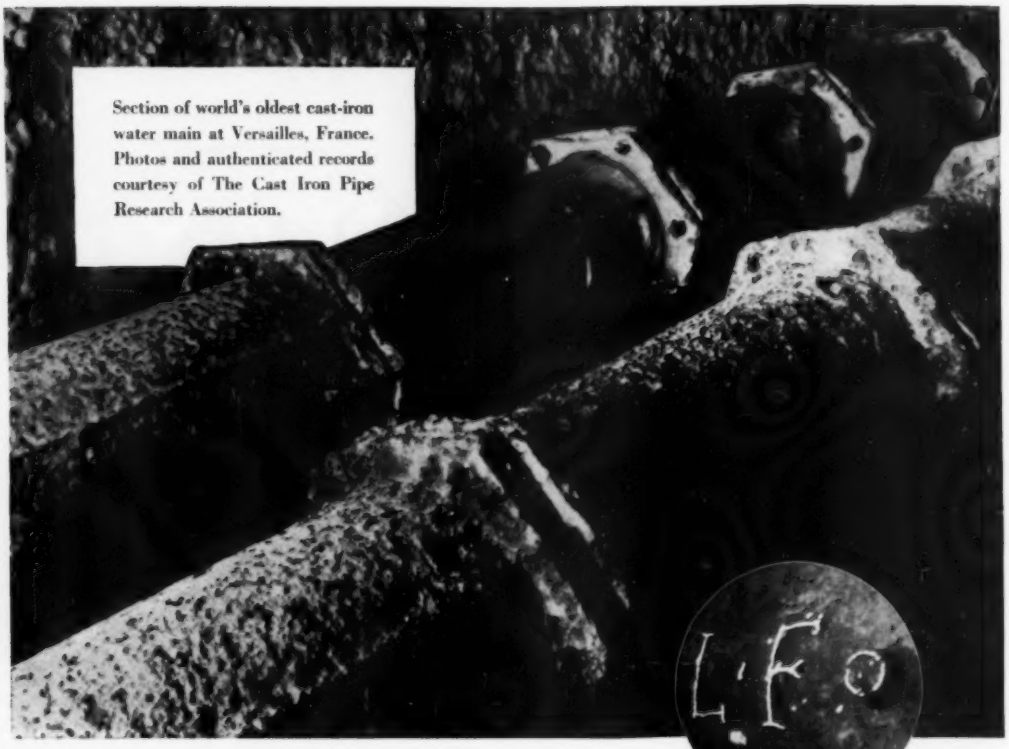

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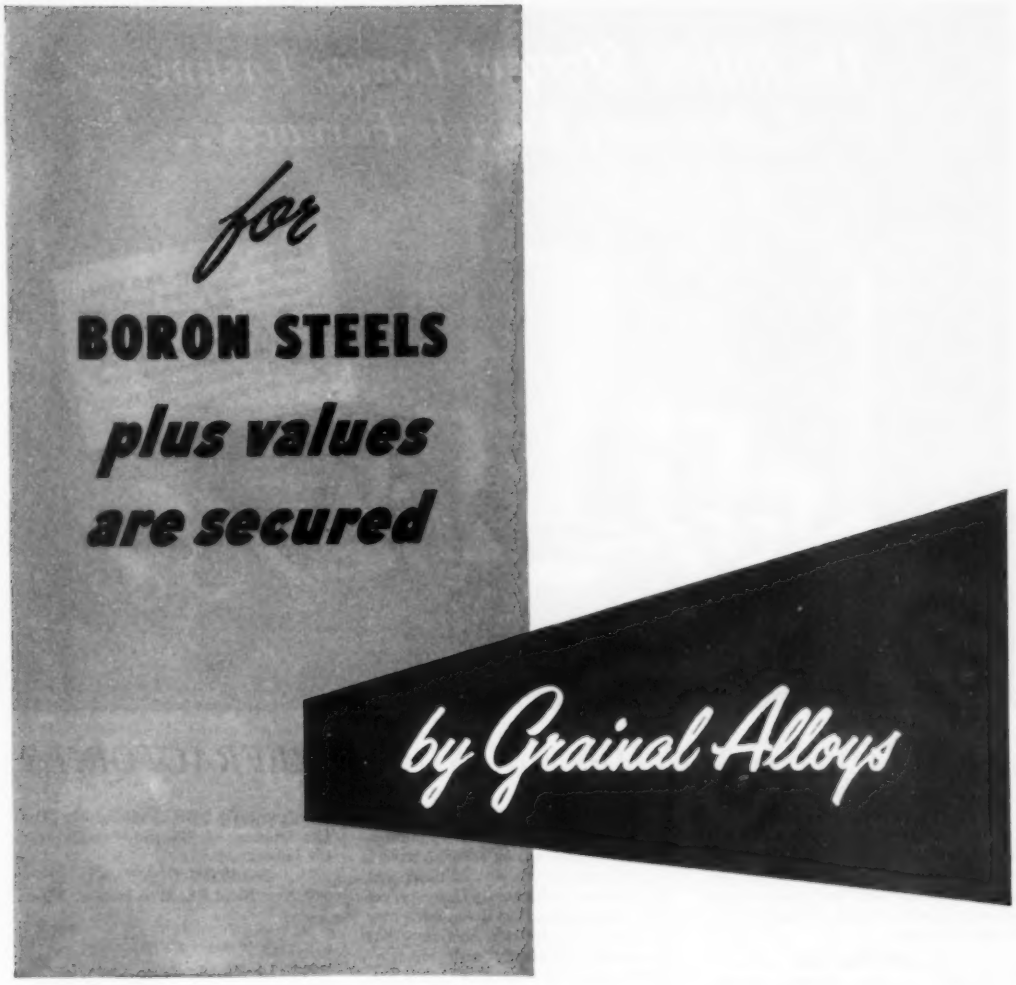

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June, 1951

Volume 59, No. 6

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Cover by Norbert Frosch

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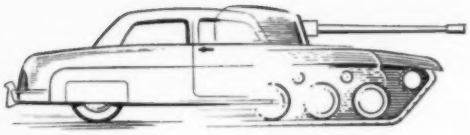

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World Metallurgical Congress

THE World Metallurgical Congress has already been announced to members of the American Society for Metals in "Bill's Column" on the flap inside *Metal Progress*' front cover and in articles in *Metals Review* for April and May. The first moves toward this project were made late in 1949 by ⊜ President Focke and Secretary Eisenman, and it was hoped that the Congress could be held last fall. Time, however, was insufficient for adequate development and it was postponed until this coming October.

In fact, the idea of an international gathering for pooling information on metallurgical progress had long been under consideration. In the early 1940's the war interfered. Immediately after the war such a meeting would have been especially helpful in clearing away a half-decade of fog, but at the time the shortage of transport and difficulties in passports and monetary exchange erected impossible barriers. More recently, it appeared that such a project would harmonize with the fundamental idea of the Marshall plan — to aid the free European nations in re-establishing a sound economy — and as such it was presented by the American Society for Metals to the Economic Cooperation Administration, and it received the instant approval of Paul Hoffman, then director of E.C.A. in Washington. He especially welcomed it as the first offer of substantial assistance his administration had received from a large American organization.

Between proposal and the actual Congress a mountain of work intervened. After E.C.A. approval it was necessary to get the idea accepted by a dozen European governments, for each had to appoint a score of metal engineers and scientists and arrange for their transportation. The ⊜, in turn, had to plan numerous four-week study tours through appropriate branches of American metal industry, arrange for transportation, hotels, and local conferences, and finally to organize a series of special meetings at the Society's annual convention. The entire project was formulated in detail so our foreign visitors could know precisely what they would be getting. Likewise, foreign members of the ⊜, and the ambassadors and metallurgical industry in other countries not receiving Marshall-plan aid (Australia, India, South Africa, Brazil — to name a few) were informed by letters and special brochures.

Dr. Zay Jeffries, past president ⊜, and Director General of the World Metallurgical Congress, visited all the western European capitals early this year and explained the project to governmental representatives and members of the metallurgical fraternity. His trip was so successful that a full contingent of European experts is now assured. Assembling in New York City on Sept. 17, these men, as well as others from other free countries of the world, will be grouped according to principal professional interest and proceed on the appropriate one of the eight guided study tours.

A typical day on these tours will include a plant inspection, a period for discussing operations and observations with plant executives, and a dinner attended by members of the local Chapter of the ⊜ where related aspects of American metallurgical industry can be considered.

All tours will converge on Detroit on Oct. 13, when the foreign metallurgists will be made welcome to the Metals Exposition and to all technical and social sessions of the cooperating societies. A special program has also been set up for them but it is of such length that it will be described in a subsequent issue. Most important will be the appointment of an "opposite number" to each foreign conferee from the ⊜ membership — an American whose technical, scientific and business interests parallel as nearly as possible those of the foreigner's. The opposite numbers will be present at the discussion groups and special general meetings which will constitute the World Metallurgical Congress, and in this way the fullest information about American practices can be transmitted to best advantage.

It is apparent that unnumbered members of the American Society for Metals will have an opportunity (both in their home city when a tour group may be present, and at Detroit during the annual convention) for exchanging ideas with foreign experts, ideas which will be mutually valuable in increasing metallurgical production, conserving man power, and utilizing scarce materials to best advantage, thus promoting the common good and safety of free men everywhere. ⊜

By D. Hart and
W. R. Tomlinson, Jr.
Research Laboratory
Picatinny Arsenal
Dover, N. J.

Use of Finely Divided Metals in Explosives

WHEN the ordinary citizen (or even the professional metallurgist) thinks of the utilization of metals in modern warfare he thinks of tanks, guns, shell, bombs, planes, equipment, and machinery of all types. The utilization of considerable amounts of powdered metals in explosives and pyrotechnics is, however, quite unfamiliar to most of those outside Ordnance, yet in 1943 almost 200,000,000 lb. of magnesium powder, or about half the total production of the metal, was used for incendiary bombs and flares.

Literally millions of bombs, with explosives metallized to increase blast, were dropped on Axis targets, while countless mines and torpedoes were dispatched against submarines and other military or cargo vessels. Explosives containing powdered metals, principally aluminum, were also used in mines, grenades, and large shell; while this use did not represent a very large proportion of the available supply during the past war, it will figure to an important degree in a future emergency.

Pyrotechnics are also dependent upon the proper use of metal powders. Flares are invaluable for night fighting of all sorts; colored signals and smokes for communication and rescue; airport landing lights for foggy atmospheres; photoflash bombs up to a half-billion candle power — all these depend on metals.

In fact, pyrotechnics utilize, in their various types, the most diversified assortment of elements, metallic and nonmetallic. Of the powdered metals, magnesium, aluminum and their alloys are employed in greatest quantity. A glance at column 4 of Table I shows that the equivalent heats of formation of the oxides of magnesium and aluminum are greatest for the metals considered. (The "equivalent heat of formation of the oxide" $\frac{-\Delta H}{n}$ is the heat of formation in kg.cal. per mol, divided by the valence of the metal in its normal oxidation state.)

Pyrotechnic compositions are physical mixtures of powdered chemical compounds and elements, which, upon reaction and combustion, produce light, heat or smoke. Although radiant energy is emitted in the ultraviolet, visible and infrared regions, flares, signals, tracers and photoflashes ordinarily need only visible radiant energy.

Up until about 1926, powdered aluminum was employed as a fuel in military pyrotechnics. This was produced by either stamping, milling, grinding or atomization. It was known that much more of the visible radiation (light) was produced when powdered magnesium was used in place of aluminum. Furthermore, it was less difficult to manufacture deeply colored signal compositions with magnesium than with aluminum powder; the latter produced light that tended to wash out or mask the color. However, in 1915 the price of magnesium was $5 per lb. and the annual consumption only about 87,500 lb. In 1926 the price had dropped to 80¢, while the annual consumption rose to over 300,000 lb. This was only the beginning. In the war year of 1943 the price of magnesium metal (not powder) was 20½¢ per lb. and 360,000,000 lb. was consumed in the United States — about ten times the average annual postwar consumption (1946 to 1950 inclusive).

Although magnesium was used occasionally for commercial pyrotechnic purposes as far back as 1865, it was not until 1926, when magnesium powder became available commercially at a

much lower price, that it was regularly introduced into military pyrotechnic compositions. In those years the production of ammunition, including pyrotechnics, was very small, the demand for powdered metals (in particular aluminum and magnesium) was also very small, and the Armed Services depended upon commercial powders developed, not for military purposes, but for peacetime applications. As is well known to readers of *Metal Progress*, at the outbreak of World War II the supply of aluminum rapidly became critically short and very little magnesium powder was available, so the production of both of these metals was stepped up very rapidly.

Other powdered metals are now used for various military purposes and are likely to be in demand in the rearmament program. Thus, magnesium-aluminum alloys, zirconium, nickel, titanium, silicon, iron, manganese, zirconium-nickel alloy powders and the hydrides of zirconium and titanium are used in incendiaries and tracer ammunition, as well as in nongaseous delay powders, igniters and priming compositions, which form an important part of the explosive train in fuses and detonators for bombs, cartridges, mines and rockets.

While pyrotechnic and related compositions have used aluminum, magnesium and their alloys for a considerable time, the application of the others mentioned above is a development of the past war. Much remains to be learned, however, and work in this direction is actively in progress, both here and abroad. This is even more true if explosives are considered. To date, powdered aluminum is practically the only metal studied in any detail and the surface of this area has hardly been scratched.

Bomb Burst (Terminal Ballistic Studies) at Aberdeen Proving Ground

Table I — Properties of Powdered Elements Used in Modern Military Ammunition

Element	Density	Melting Point	$\frac{-\Delta H}{n}$ Kg.Cal.	Heat of Oxidation Cal./G.	Adiabatic Temperature of Oxidation
Magnesium	1.74	651° C.	73.05	6,000	12,200° C.
Beryllium	1.85	1280	69.50	15,500	11,600
Aluminum	2.7	660	66.5	7,400	13,300
Zirconium	6.4	1860	64.5	2,830	14,300
Boron	1.73	2300	56.63	15,600	11,300
Silicon	2.4	1420	50.8	7,200	11,300
Titanium	4.5	1727	56.25	4,700	12,500
Manganese	7.2	1260	46	1,680	7,700
Phosphorus, red	2.2		36	5,800	8,600
Iron	7.86	1535	33.3	1,770	6,600
Nickel	8.9	1452	29.2	990	4,800
Antimony	6.7	631	27.7	680	5,500
Lead	11.3	327.5	26	260	4,300

Metal in Explosives

Powdered aluminum is incorporated in explosives in two ways, determined by the type of explosive, and the loading method by which the mixture is to be placed in the ammunition: *(a)* Dry blending with a granular composition, or *(b)* introduction into a fluid slurry under constant agitation. The first type of mixture is pressed into the component (say a shell), while the second is poured (cast) and allowed to cool and solidify. The factory or arsenal is immediately faced with problems concerning the safety of handling, loading and storing the explosive, and aluminum figures in this to an important degree.

For instance, the first question to be asked is, "Can the explosive be handled safely?" The laboratory would answer that by reporting some tests measuring the sensitivity of the mixtures to impact, reporting the results in relation to the sensitivity of an explosive like TNT for which much experience is recorded. Thus, Fig. 1 shows the sensitivity of two explosives representing the two types mentioned above, RDX (Composition A) and TNT, when mixed with various amounts of powdered aluminum. It shows that TNT with 50% aluminum is five times as sensitive as the metal-free explosive; RDX (A) is over three times. These maxima represent a dangerous sensitivity, especially when the material is dry and loose, and this deduction is amply verified by experience during 1940-1945. Fortunately, the sensitivities shown in Fig. 1 are materially reduced if the metal is waxed and the metallic particles thus separated from the explosive chemical by what amounts to a desensitizing barrier.

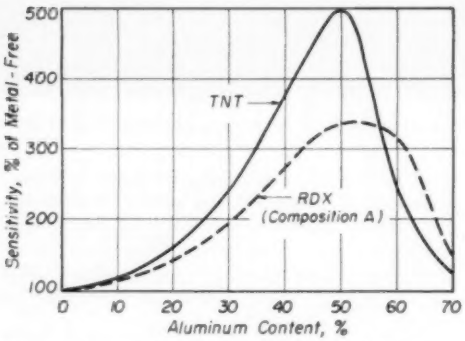

Fig. 1 — Impact Sensitivity of Aluminized Explosives

The second consideration is, "Can the explosive be stored safely, and will it withstand such storage without impairment of its properties?" Aluminized explosives can be made which are stable, but certain constituents should be avoided and certain precautions taken. For instance, ammonium nitrate will react with aluminum very rapidly in the presence of even traces of moisture. In a mixture of NH_4NO_3, TNT and Al (plus a little H_2O) ammonia is released and it will react with TNT to form a loosely bound diammoniate which will ignite as low as 96° C. Such a reaction has led to explosions in steaming-out operations (shell recovery) which are normally quite safe. Further, moisture must be removed and the explosive kept dry, else moisture will react with aluminum and produce hydrogen, which will reduce the oxidizing $-NO_2$ groups of explosives. This leads to excessive gassing, distortion of the component, and extensive chemical decomposition of the charge. These are either dangerous or detrimental to the ammunition's usefulness.

Naturally, the aluminum is added to the explosive for a specific purpose, and we will now discuss this in a general way.

Performance Properties

There are three performance properties of an explosive of primary interest: *(a)* Destructive power, *(b)* propulsive power, and *(c)* brisance. The first factor is a measure of various properties such as ability to create air blast and underwater or underground (cratering) damage; the second is a measure of ability to throw a projectile or move a burden of earth; the third represents ability to shatter at the surface of the charge (fragment the projectile into small missiles which are projected against the enemy at high velocity).

In the study of such performance features, specialists have devised certain tests. For instance, measures of energy content Q, rate of detonation D, and "hot gas volume" are often made. The "hot gas volume" is the quantity defined as nRT, where n is the number of moles of gas formed in the explosion, R the gas constant, and T the temperature of explosion. Aluminum powder has a markedly beneficial effect on the Q and nRT of many explosives but, as might be expected, only within certain compositional limits.

Curves in considerable number could be presented to show the effect of increasing proportions of aluminum on the above performance properties of widely used military explosives, but they would be of little interest to an article for the nonexpert. Suffice it to say that about 15% aluminum gives the maximum advantage in improving Q (the energy content of TNT) and the nRT value (its hot gas volume). The values are 120 and 130%, respectively, of the aluminum-free explosive. However, D, the rate of detonation, is decreased from an original 6800 m. per sec. to 6600 m. per sec. In fact, when aluminum is added to any explosive having a high D, its effect is to depress this rate of detonation over the entire compositional range. This behavior is due to the aluminum's thermal conductivity, its effective screening action on the detonation wave, and to the added fact that, in detonating, the explosive (TNT here) reacts so rapidly that aluminum is essentially inert.

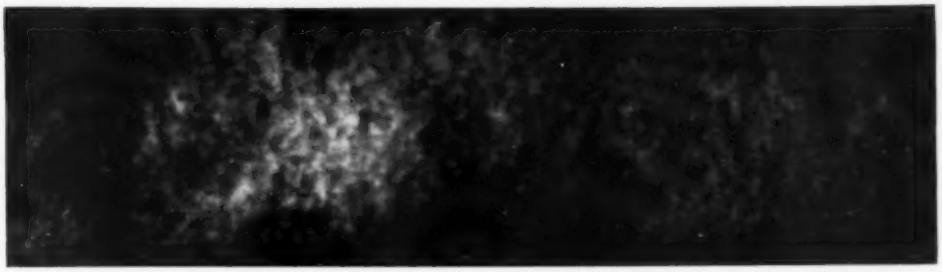

Fig. 2 — Radiograph of Cast Explosive, 75% TNT, 25% Aluminum Metal in Powdered Form

It might be interesting to note that different effects result from adding aluminum powder to ammonium nitrate — a material which is difficult to detonate, and has the relatively slow detonating rate of about 2000 m. per sec. Any fine aluminum present then has time to oxidize and adds its large heat to the energy released by the nitrate, and this can therefore increase the rate of detonation by 50% in a mixture with 20% aluminum.

As an example of the value of such information it might be pointed out that D is an excellent measure of brisance — that is to say, the shattering power.

Other properties of metal-explosive mixtures are interesting to the explosives chemist, such as specific heat, thermal conductivity, compressive strength and Young's modulus of elasticity. Enough has been said, however, to illustrate the fact that certain advantages from an energetic standpoint are obtainable through the addition of aluminum to explosives used for bursting charges, as well as some improvements in propulsion, without undue impairment in other properties.

Propellants and Primers

One might logically ask whether the same could be said about propellants. Since good propellants have high rates of reaction and liberate high amounts of heat, it would indeed be expected that the exothermic oxidation of metals would hasten burning, since it is obviously a surface reaction. Although not much work in this field has been done, it has been found that the addition of powdered magnesium to propellants increases their rate of burning and thus the propulsive ability they possess.

The chemical elements or compounds responsible for the ignition of propellants also may include powdered metals. This recent innovation resulted from a desire to replace the hygroscopic black powder, traditionally used, with a nonhygroscopic composition. The sensitivity of black powder to water is most undesirable, as the old standard material then functions quite erratically. The current position was reached after the very hygroscopic charcoal of black powder had been replaced by a nonhygroscopic organic compound, and the potassium nitrate was treated to render it less hygroscopic. Even then it was felt that this modified black powder still left something to be desired; furthermore, much difficulty is involved in its manufacture — it must be wheel-milled to increase particle fineness and intimacy of contact, and then pressed into pellets and "corned" (broken up to a specified granulation).

Aluminum, magnesium, zirconium, certain metal oxides, and the nonmetal silicon have been utilized to correct this situation. The composi-

tions developed to date are extremely easy to prepare, and produce much more heat per equivalent weight or volume than black powder.

Primers — One of the most important types of chemical mixtures is the one which starts the train of events, that is, the initiators or primers. These assure the proper functioning of bombs, shell or mines, and even initiate the ignition elements in cartridge cases. To increase their heat and sensitivity, powdered metals such as aluminum and zirconium have been employed. The nonmetals sulphur, phosphorus and silicon have also shown some virtue.

The outstanding feature displayed by metals in all the above applications is their high heat of oxidation. Thus, in explosives they contribute energy to the process of explosion; in propellants they contribute substantially to thrust; in primers they markedly increase the range of action. It seems almost inevitable that a highly exothermic combustion means rapid and strong reaction — a reaction that is difficult to quench. It is not surprising, then, that pressed, powdered magnesium was utilized by all the belligerents of the past World War as an incendiary agent.

Safety Against Dust Explosions

Most of these powdered metals are pyrophoric and may be sensitive to ignition. In handling and using them, it must be remembered that they are combustible solids which can produce a dust explosion if dispersed in air and ignited, just the same as coal dust, flour, starch and other combustible organic materials.

Very little is known of the basic mechanisms of ignition of dust particles, or of the method of propagation of the flame and the explosion wave. While the explosibility of metal powders depends upon many factors, such as ignition temperature, size, particle size distribution, shape and surface structure of the particles, minimum energy required for ignition, and moisture content, the metals may be arranged in decreasing order of explosibility of their dusts:

Zirconium and titanium (usually shipped under water or alcohol)
Magnesium (less than 200 mesh)
Magnesium-aluminum alloy (less than 200 mesh)
Aluminum (less than 6 microns)
Zirconium-nickel alloys
Silicon

Under certain conditions the human body may build up and discharge electrostatic spark* energies as great as 0.001 joule. This is of the order of that required to ignite dust clouds of zirconium and some types of magnesium powder. Therefore, precautions must be taken to ground plant equipment and to prevent the accumulation of static electric charge on workmen wherever these highly flammable metal powders are manufactured and used.

Nearly all the magnesium powder was ground mechanically during the last war. Because of various manufacturing methods, different particle shapes and surface structures were obtained, so that powders having the same sieve granulation did not have the same surface areas. Considerable difficulty was therefore experienced in obtaining the required burning rates and light intensities of pyrotechnics. The use of atomized magnesium eliminates this difficulty. Furthermore, the minimum energy required to ignite dust layers and clouds is much greater for atomized than for milled and stamped magnesium.

Atomized magnesium is obtained by blowing a stream of helium or natural gas across a small nozzle from which molten magnesium is flowing under pressure. Another advantage over ground or stamped magnesium is that the atomized product has a much higher apparent density, so that more metal can be put in pressed or pourable compositions per unit volume. Further, since particles of spherical shape flow easily and present a minimal, smooth surface per gram for a given size, they are easier to protect by surface treatments and have an intrinsically lower reactivity in undesirable reactions, such as slow oxidation with water.

Summary

It is evident to ballisticians that relatively large quantities of powdered metals will be required in the national defense effort for pyrotechnics and explosives. The present production is inadequate; additional facilities for manufacture will be needed. While considerable progress has been made in their application, their utility is certain to be further expanded when the results of current research programs can be appraised and activated.

*Editor's Note — A fortunate byproduct of the atomic energy program is a simple instrument for eliminating static accumulations in annoying or dangerous situations. The principle depends on the fact that radioactivity generally ionizes air in the vicinity, and when such ionized air comes in contact with charged surfaces or particles, the charges neutralize each other. The instrument may be a holder for properly protecting thin foil or electroplate of an active element and this can be brought near or into contact with the sources of static at intervals. Or an air nozzle can be lined with radioactive foil, and the stream of ionized air issuing from it will effectively discharge static accumulations in the vicinity.

Hot Metal Machining*

By Sam Tour
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New York 6, N. Y.

WITH the hot spot machining technique, metal removal rates for low carbon, medium carbon, chromium, nickel and stainless steels have been increased three and four times over those possible with conventional machining. Certain of the high-temperature alloys that are supposed to be difficult to machine are readily machined with this method. For example, Allegheny Ludlum Steel Corp.'s S-816 (which contains about 42% Co, 19% Cr, 19% Ni, 4% W) was machined at a rate of 270 cu.in. per hr. The usually recommended metal removal rate for this hard-to-cut material is 2.1 cu.in. per hr. We exceeded the recommended rate a hundred-fold by heating it to 1500° F. and machining it as rapidly as it was heated. This heating at the time of cutting forms the basic concept of hot spot machining.

By heating the stock at the time it is being machined, we take advantage of certain metallurgical properties that exist at the elevated temperatures of the metals. In order to explain how these can be of benefit to metal removal, let's consider what happens when a cutting tool is pushing off metal. The force exerted on the stock by the tool is utilized in three ways: To shear the stock, to deform the chip after it leaves the point of contact between tool and work, and in the friction created by the chip as it is pushed across the top of the tool.

These three actions absorb energy. The amount of energy consumed in shearing the stock is a direct function of the shear strength of the material. The amount of energy needed to deform the chip is an inverse function of the stock's plasticity. Energy consumed by friction is also a function of shear strength. Therefore, if you can lower the shear strength of the steel, you will lower the energy required for the shear cut, you will lower the energy required to deform the chip, and you will lower the pressure on top of the tool and the friction energy. The effect of temperature, notably the higher temperatures, is to reduce the strength of steel and make it easier to deform. This relationship for tensile strength is shown in Fig. 1 (courtesy National Tube Co., Bulletin 26). As the temperature of the stock is increased, the amount of energy required to overcome each of the three factors is decreased.

It would seem obvious that the addition of a coolant will keep the shear strength on the high side whereas we want it as low as possible to make shearing easier. Vitallium, like S-816, is a high-temperature type of material which is not

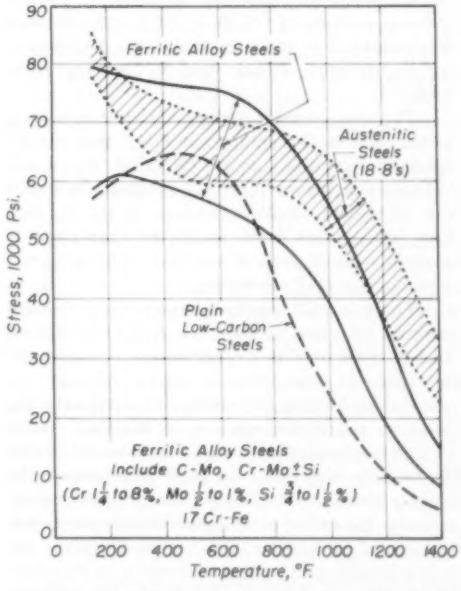

Fig. 1 — Influence of Temperature on Tensile Strengths of Various Steels. Elevated metal temperatures have similar effect on shear strengths

*This article is based on comments made by Mr. Tour at one of the high-production sessions at the October 1950 A.S.M. convention in Chicago.

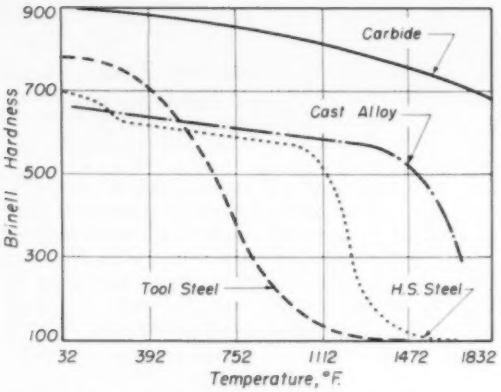

Fig. 2 — Relationship of Tool Tip Temperature and Hardness for Different Tool Materials

supposed to be machinable. With hot spot machining, we can take a ¼-in. depth of cut with 0.030-in. feed at 150 surface ft. per min., just throwing chips off. It is readily machinable if you heat it up to 1500° F. Stainless steel and similar alloys machine readily. The surface comes out quite smooth and, due to the low load on the tools, the tools stand up.

It is not necessary to go to incandescent temperatures. At 500° F. there is a decided improvement in chip removal, it is something on the order of a 50% increase. At 1000° F., there is 100% improvement. A 200 to 300% improvement was obtained in the machining of a 150,000-psi. tensile strength nickel steel by heating it to 1500° F.

The improvement realized with this technique is not only in the amount of metal that can be removed but also in the finish of the work. When a really heavy cold cut is taken, the under side of the chip looks quite smooth but the surface of the work from which the chip came is covered with all sorts of crevices. That does not occur in hot spot machining.

There is still another improvement besides pushing off more metal much easier. The load on top of the tool is a combination of the shear, deformation and friction forces. These are reduced by heating the stock. To determine the loads we put dynamometers on the tool. After we had determined the actual loads, we calculated the tool-tip pressures. In good, fast cutting, the tool-tip pressures for room temperature cutting were on the order of or over 500,000 psi. That is a lot of pressure. If the work ahead of the tool is heated, you cut the load down to the order of 200,000 psi., which is well within the strength of carbide tools, even at 1800° F. It is obvious, therefore, that if the tool bears less load while cutting, its life will be extended. The same principle applies to either hot spot cutting or hot cutting.

There is no need to cool the tool. We used inserted-type carbide tool bits, Carboloy Grade 78B and Kennametal K3H. Figure 2 (from Schmidt and Roubik) shows the effect of temperature on the hardness of tool materials.

In hot spot cutting, we heat just as fast as the tool moves. High frequency induction heating is very simple and easy to control. It is not necessary to heat to full temperature the complete depth of the cut. In fact, this doesn't happen because heat penetrates from the surface. Therefore, if you are taking a ⅜-in. cut, the surface temperature may be 1500° F. At the point of the tool or the base of the cut, it might be only 1100° F.; below that the heat falls off very rapidly. This applies to full hot machining. The important point to remember is that the material does not have to be heated to the upper ranges. A big improvement takes place by heating to only as high as 500° F.

We use a coolant on the work after the cut is taken. This is done to minimize the expansion against the tailstock of the machine. Incidentally, we use a special tailstock to take up the expansion.

Feed lines are formed, but they travel around the periphery. In cold cutting you get lines transverse to the cut. These are tear lines in the surface caused by the tearing away of the chip. Tear lines don't develop when the material is hot.

Our present common speeds are too slow not to get tear lines on cold cutting steel with heavy cuts. If you could build a machine to take a heavy cut at 1000 ft. per min., you wouldn't get tear lines — even with cold machining. Tear lines don't occur during hot cutting because the steel doesn't have the tendency to cold fracture and for the fracture to penetrate.

Some work has been done on very high speed cutting that I don't believe was mentioned here. Apparently, the geometry that takes place at the point of a tool changes at some critical speed, and if you get up to better than 1000 surface ft. per min., some remarkable cuts can be made. The machine will tear itself apart and tools will fail at 500 ft. per min., but at 1000 ft. per min. it will sail through indefinitely.

There are very few machine tools that will stand the gaff, but as those new machine tools are built for machining at 1000 and 2000 surface ft. per min., a lot of things will be done that have not been done in the past.

Preparation of Very Fine Wire by Electropolishing

By William H. Colner
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Armour Research Foundation
Chicago

Wire finer than 0.0003 in. has been prepared by chemical etching, but this method is often unsatisfactory because of non-uniform and uncontrollable dissolution. However, these difficulties can be overcome by continuous electropolishing.

While the fundamentals of electropolishing have been known for some time,* its application to the production of fine wire is new. The small size of wire leads to operating features that are quite different from the usual process. The conductivity of metal is usually so much greater than that of the polishing solution that the whole piece being polished is practically at uniform potential. But in the case of fine wire, the surface-to-volume ratio (which is inversely proportional to the diameter) becomes so large that most of the current is carried by the solution near the point where the current enters, and very little is carried along the wire in the solution. As a result, nearly all the polishing (dissolution) takes place over a short length of the immersed wire. For a 0.001-in. wire, the polishing section is from 1 to 2 in. long, the maximum rate of polishing being at the solution line.

Therefore, a batch process cannot be used for producing fine wire. On the other hand, if the wire is fed through the bath at a steady rate and under constant electrical conditions, each element will receive the same treatment, and the wire will emerge with a uniform cross section.

One advantage of this method is its self-regulating characteristics: As the current density is increased, the rate of metal dissolution slowly approaches a "saturation point", at which relatively large increases in current cause little change in wire diameter. In other words, the efficiency of dissolution falls with increasing current density. Close regulation and good

IN RECENT years, there has been a stepped-up demand for ultrafine wire, which has resulted in the consideration of new production methods. For example, miniaturization developments in electronics use ultrafine wire in miniature tubes and in circuit components (precision resistors). Other possible applications are small thermocouples, and low-inertia, low-volume coils in miniature instruments. Increased availability of fine wire might be expected to lead to new uses. The Naval Ordnance Laboratory was interested enough in the matter to contract with Armour Research Foundation to study and perfect methods for its use.

Fine wire, down to 0.0003 to 0.0004 in., is usually prepared by drawing through a series of dies. The manufacture of such diamond dies is a very costly and time-consuming operation, and the fine wire is correspondingly expensive. (For example, the price of 0.0004-in. wire is ten times that of 0.001-in. wire.) The small drills required must be kept centered by centrifugal action in high-speed, yet vibrationless, machinery. Drill size also limits the final diameter and roundness that can be attained. Operations have to be followed under a microscope, and require highly skilled craftsmen. Work hardening of the wire is another problem; annealing between passes is often required.

From the above brief statement, the limitations of mechanical drawing are obvious.

*An extensive bibliography on electropolishing was given in "Surface Preparation by Electropolishing", by C. L. Faust, *Journal*, Electrochemical Society, Vol. 95, March 1949, p. 71c.

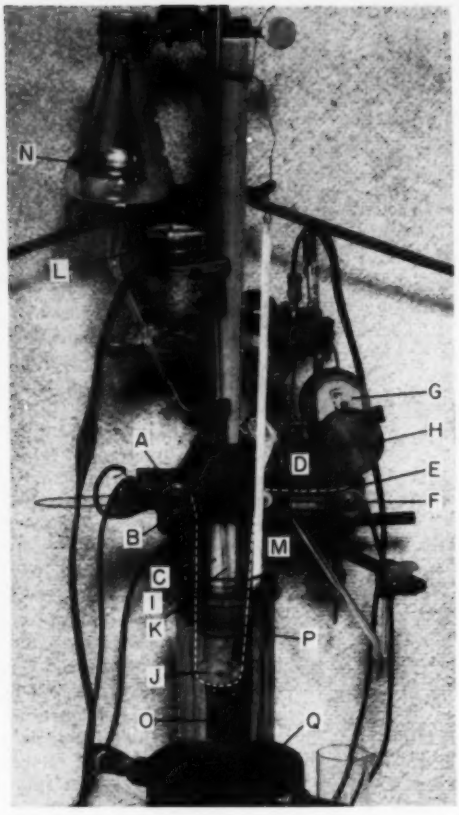

Fig. 1 — Details of Electropolishing Assembly; Dotted Line Shows Path of Wire

A. Wire feed spool. B. Mercury contact to rotating spool. C. Mercury contact to feed current into wire. D, E. Mercury contacts 1 in. apart, for the continuous measurement of resistance. F. Take-up spool. G. Clock motor. H. Driving pulley. I. Teflon rod. J. Teflon pulley. K. Helical stirrer. L. 60-r.p.m. stirrer motor. M. Wire rinse. N. Rinse water reservoir. O. Cathode. P. Water jacket. Q. Hot plate, continuously controlled.

reproducibility of wire diameter thus can be attained by controlling the polishing current.

The setup used in our work is shown in Fig. 1. The current was drawn from the laboratory's power supply (voltage regulated) with considerable series resistance; such a system gave a stable current, unaffected by small variations in contact resistances.

The wire diameter was determined continuously by measuring its resistance for a 1-in. length. A special ohmmeter was constructed for this purpose, whose scale readings were converted to resistance and wire size by calibration curves. Since the system was designed for making extremely fine wire, all frictional resistances were kept low. Thus, the feed spool (A) was provided with sapphire pivot bearings on which the tension could be adjusted so as to keep the wire taut. Contact to the wire at D and E for resistance measurement and at C for current lead-in was made by passing the wire through a mercury film held on a copper hairpin. (This method, of course, is only applicable to non-amalgamating materials.) An additional contact for current lead-in was provided by having the feed spool rub against a mercury drop contained in cup B, B and C being interconnected.

The wire was pulled by a 1-r.p.m. clock motor G; wire speed could be altered by varying the size of pulley H.

From the feed spool, the wire was pulled through the solution over a "Teflon" pulley J mounted on a shaft and held by a rod of the same material. (Pulley J is round; photographed through side of cylinder it appears distorted.) It was chosen for its resistance to all electropolishing solutions, both acid and alkaline, at all common polishing temperatures. Good temperature control of the bath was maintained by a water jacket P, a stirrer K, and a continuous control hot plate Q. The stirrer was driven by a 60-r.p.m. clock motor L, in a way that the agitation was not sufficient to damage the wire. Rinsing of the wire was accomplished at point M, where a drop of water was held by capillary attraction between the tip of a capillary supply tube and a glass rod.

Work on 18-8 (Type 304) stainless steel will now be detailed. Two sizes of starting material were used: 0.001-in. annealed wire and 0.0004-in. hard drawn wire. The procedure, however, is applicable to other metals and sizes, possibly with slight modifications.

The bath that gave the best results in this work had the following composition; it had practically no local action on the stainless wire:

Phosphoric acid (85%)	125 cc.
Water	30 cc.
Citric acid	50 g.
Ethyl alcohol (95%)	10 cc.

The composition of the bath can be varied over a considerable range without appreciably affecting the polishing action. We believe that almost any solution commonly used for electropolishing stainless steel could be adopted.

It is essential to have the wire in motion before turning on the current. Furthermore, the full current that is required to give a certain wire diameter cannot be applied at once; some time is required to establish equilibrium polarization at the surface. Before this equilibrium is reached, the polishing efficiency is high enough to completely dissolve the wire, if

the full current is passed. It is especially important to approach the final amperage gradually when making the finest wire.

Figure 2 shows typical polishing characteristics (wire diameter as a function of current) at a fixed speed of 4.7 in. per min. It is readily seen that the current efficiency of dissolution decreases considerably as the current increases. For instance, at 65° C., a current of 5 milliamperes will remove 44% of the original metal; increasing the current to 15 will remove 69%. In other words, the additional 10 milliamperes remove only 25% of the original metal.

Starting with 0.0004-in. hard drawn stainless steel wire, we could make wire 0.00015 in. in diameter consistently. The finest size of wire attained was 0.00013 in. It is possible that even finer wire can be made with some refinement in the apparatus.

The curves also indicate that the current efficiency is lower at lower temperatures — that is, a limiting rate of metal dissolution is approached faster. Operation at 80° C. was satisfactory for most purposes; control was good and the effect of small temperature fluctuations unimportant.

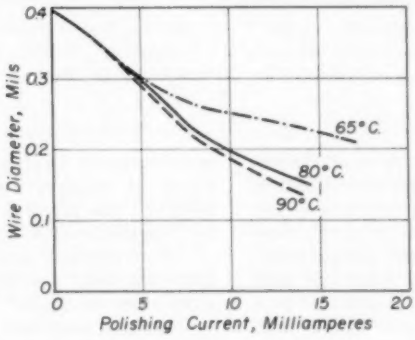

Fig. 2 — Electropolishing Characteristics of 0.0004-In. Hard Drawn Stainless Steel Wire; Wire Speed Held Constant at 4.7 In. per Min.

Figure 3 shows the effect of wire speed on the polishing characteristics of fine wire. As indicated before, the effective polishing zone extends to about 1 to 2 in. below the solution line at the point of current entry, and the faster the wire travels, the less time each element of wire will be exposed to polishing. At the speed of 9.5 in. per min. (24 cm. per min.), enough current was passed through the wire to bring it to red heat above the solution line, yet it was impossible to polish the wire under those conditions down to the finest diameters that were attainable at lower speeds with only a fraction of the above current. A high temperature in the wire just before it is immersed is not objectionable as long as the wire does not burn out; any surface oxide that forms will be eliminated in the polishing process. Auxiliary means might be devised to cool the wire, if necessary, to achieve optimum conditions in production.

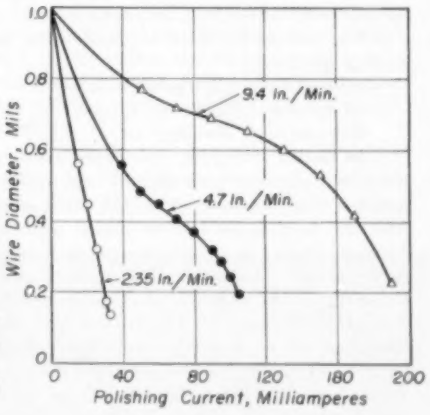

Fig. 3 — Influence of Speed on the Electropolishing of 0.001-In. Annealed Stainless Steel Wire; Temperature of Solution Held at 80° C.

It is desirable to operate at the highest speed compatible with the desired degree of polishing. In addition to the increased rate of production, the operation is more reproducible and controllable. From the above, it follows that the depth of immersion of the wire is immaterial as long as it is great compared to the length of the polishing zone.

Agitation, by helping remove the anodic film, increases the polishing efficiency. Excessive agitation damages the fine wire, but a small amount of circulation is desirable to maintain uniform temperature and anode film conditions.

The type of bath influences polishing characteristics, and curves similar to those in Fig. 2 must be determined for each. Freedom from local action is a determining factor in the choice of polishing solution.

In summary it may be said that stainless steel wire, and wire of other metals and alloys, may be reduced in diameter, far below the limit possible by conventional wire drawing practices, by a readily controllable process of continuous electropolishing. The product's eventual fineness is determined chiefly by wire speed and polishing current, once composition, temperature and agitation of bath are under control.

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University of Ghent, Belgium

Spherulite Formation in Nodular Cast Iron

OUR STUDY of the mechanism of spherulite formation in nodular cast iron is still in the preliminary stage.* Results now at our disposal, while significant, do not give a complete and precise description of the phenomenon; actually our laboratory work has been limited to quenching small samples of iron during its solidification interval and to tracing the time-temperature solidification curves of cast iron treated with magnesium.

Our researches seek to answer the following questions:

How are the spherulites formed?

At what point are they formed?

How do they develop?

In *Metal Progress* for June 1950 we presented electron micrographs and spectrographic analyses indicating that the spherulites in magnesium-treated irons probably contain nuclei; *a priori* one could imagine they are some magnesium compound such as sulphide, oxide, carbide or complex carbide containing silicon and magnesium. It could therefore be conjectured that the unstable particles of carbide decompose into their elements, and that the carbon therefrom would attract and orient atoms of carbon from the immediate vicinity.

Although this seems possible, it is not to be considered as established; indeed, one should remember that spherulites have been obtained by a great many different elements (Mg, Ce, Ca, Ba, Li, Sr, Na, K, Te . . .) and even *without* any addition. Some spherulites were obtained by superheating and rapid cooling of very pure synthetic iron (an alloy of iron, carbon and silicon). However, that iron was melted in a magnesite crucible, and spectrographic analysis proved the presence of traces of magnesium, traces of the order of 0.002%. The repeated experiment, but melting in an alumina crucible, gave no spherulites.

An important question to be answered is the following one: Are the spherulites born in the solid or in the liquid?

Samples quenched at a certain early stage of solidification contain austenitic dendrites, most of them enclosing one or more clearly formed spherulites, some of them very small. This is shown in Fig. 1; one of the spherulites and its matrix enlarged to 3500 diameters is shown in Fig. 2.

Note that these spherulites are still relatively small and will develop further; the one shown in Fig. 2 has a diameter of about 8 microns. If this same metal had been sand cast and normally cooled in a 1-in. round bar, the spherulites would probably reach diameters on the order of 40 to 50 microns.

First Formation of Spherulites

Therefore it seems possible that a spherulite is started by carbon precipitation from the supersaturated austenite, beginning at a certain degree of supersaturation of the solid solution. Is the very first precipitation related to an entrapped inclusion (a carbide, the decomposition of which initiates the graphitization?) or a discontinuity? At this time, a satisfactory answer cannot be given. All the observed initial spherulites in quenched samples of hypo-eutectic and nearly eutectic iron appeared to be located at the periphery of the dendrites, thus where the carbon concentration was the highest.

It should be mentioned that the micrographs,

*This research is being sponsored by the Institute for Scientific Research Applied to Industry and Agriculture (I.R.S.I.A.) and "Fabrimetal". This paper was presented to the conference held by Massachusetts Institute of Technology in September 1950 (see *Metal Progress*, November 1950, p. 729).

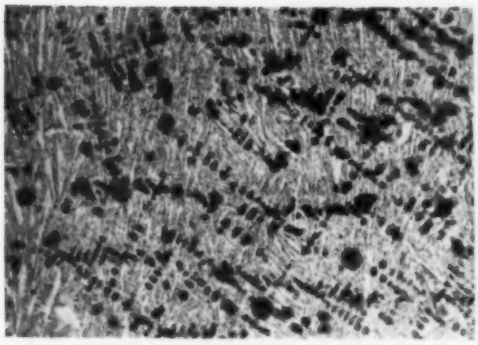


Fig. 1 — Magnesium-Treated Eutectic Iron, Quenched Early in the Solidification Stage. 100×. Dendrites of transformed austenite enclose particles of graphite

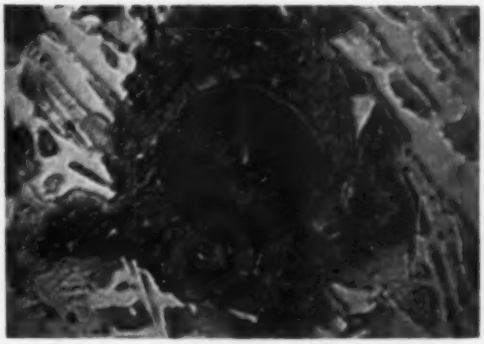


Fig. 2 — One of the Graphite Particles of Fig. 1 at 3500 Diameters. The spherulite is embedded in martensite (austenite, before quenching)

Fig. 1 and 2, refer to substantially eutectic cast irons, according to the formula:

$$C+\tfrac{1}{3}(Si+P)=4.3$$

Initial appearance of spherulites in distinctly hypo-eutectic nodular cast iron is shown in Fig. 3; Fig. 4 shows a more advanced stage of solidification of the same casting. Composition of this cast was 3.15% C, 2.38% Si and 0.05% P. $C+\frac{1}{3}(Si+P)=3.96$ (hypo-eutectic).

Please note that all this evidence refers only to a stage already plainly visible under an ordinary microscope — in other words, this is by no means the very beginning. We believe we have observed even smaller spherulites associated with primary dendrites, but the difficulty of identifying them clearly after such etching as is necessary to locate them in relation to the dendrites does not permit any positive statement.

The foregoing quenching tests seem to argue in favor of the hypothesis of the spherulite being born by precipitation of carbon out of the supersaturated primary austenite. Indeed, the appearance of minute graphite spherulites in the early stage of solidification of a hypo-eutectic iron (Fig. 3) could be interpreted as being a result of such precipitation.

However, it is more probable that those early spherulites originated during rapid solidification of a carbon-enriched liquid in the immediate vicinity of an austenite dendrite. (A. Boyles, in "The Structure of Cast Iron", p. 18, makes similar statements concerning the quenching of conventional flake graphite iron, where finely divided graphite occurred in spots.)

The appearance — or, in every case, the growth — of the graphite crystal in the solid phase immediately after solidification sug-

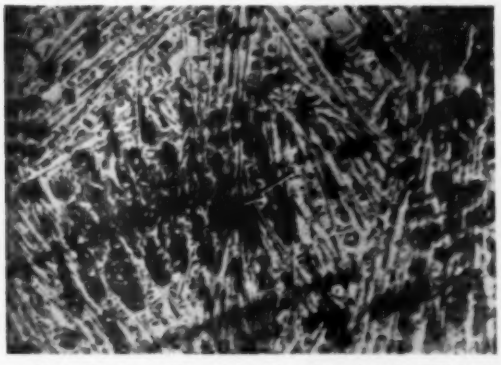


Fig. 3 (Left) — First Spherulites (One Marked With Arrow) Plainly Apparent in Primary Dendrites of a Hypo-Eutectic Nodular Iron. Fig. 4 (Right) — Same Iron Quenched From a More Advanced Stage of Solidification

gests an explanation of its spheroidal shape. What happens is that this solid metallic phase, still very plastic, nevertheless offers much more resistance to the growth of the graphite crystal than would a liquid phase, and forces this new crystal to a minimum surface volume — that is, into a sphere.

It seems equally possible that, when the graphite crystal is born and then develops at a lower temperature, the greater rigidity of the solid austenite and its existing discontinuities force the graphite crystal to develop in directions of least resistance and to produce deformed shapes. Sometimes very bizarre shapes of graphite occur in magnesium-treated cast iron; among the most curious we have encountered are those in Fig. 6 and 7, illustrating what we have called "crabs" and "forked sticks".

Time-temperature solidification curves of magnesium-treated and secondary-inoculated iron argue in favor of the above-mentioned hypothesis of spherulite formation. Such cooling curves never show a definite arrest or a recalescence corresponding to a eutectic solidification, as do ordinary gray irons of the same composition (G5 of Fig. 5) and even magnesium-treated white iron containing graphite spherulites (G4 and G4b of Fig. 5).

Furthermore, if the rate of temperature drop becomes slower (corresponding to the first stage of solidification) and a very slight but distinct recalescence toward the end of solidification, the corresponding structure is partly spherulitic graphite in pearlite and partly ledeburite or even intercellular lamellar graphite in austenite.

This fact may suggest the hypothesis of spherulites being born by precipitation of carbon from supersaturated primary austenite during supercooling along the steep slope of the temperature-time curve, the ledeburite or the flake graphite-austenite during the slight recalescence. However, the study of the quenched samples of hypo-eutectic magnesium-treated nodular iron does not allow us to conclude that the spherulites originate in the solid. On the contrary, examination of quenched samples of highly hypereutectic magnesium-treated nodular iron seems rather to indicate that the spherulites originate in the liquid phase. Indeed, by quenching such an iron at the beginning of solidification we obtained isolated graphite spherulites embedded in what we may consider to have been liquid metal at the time of quenching (Fig. 8). Composition of this iron was 4.45% C, 1.26% Si, 0.25% Mn, 0.07% P, 0.01% S, 0.06% Mg.

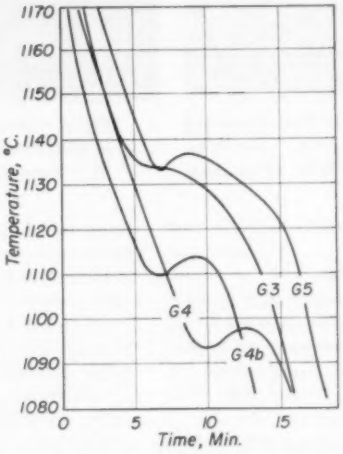


Fig. 5 — Time-Temperature Curves Taken During the Solidification of Four Melts of Cast Iron of Substantially Equivalent Composition, Except for Magnesium

	Nodular	White*		Gray
Melt.	G3	G4	G4b	G5
Carbon	3.22	3.16	3.23	3.14
Silicon	2.35	2.36	2.40	2.38
Magnesium	0.06	0.09	0.08	None
Sulphur	<0.01	<0.01	<0.01	<0.027
Manganese	About 0.5% in all melts			
Phosphorus	About 0.08% in all melts			
Nickel	About 0.75% in all melts			

*White nodular iron, without secondary inoculation, containing a few spherulites.

Another sample (Fig. 9), quenched in a slightly more advanced stage, shows groups of assembled spherulites of about the same individual size as in Fig. 7. It is rather difficult to believe that such assembled masses of spherulites could originate by precipitation of carbon from supersaturated austenite. This would imply an exceptionally high degree of supersaturation as well as a high degree of undercooling.

The temperature-time solidification curves for hypereutectic magnesium-treated iron have the same general shape as G3 in Fig. 5 for hypo-eutectic nodular iron. If spherulites are born in the liquid it seems necessary, according to the solidification curves, to postulate either direct precipitation of carbon from the liquid or, alternatively, a speed of carbide decomposition that is higher than its speed of precipitation.

We will conclude these remarks on the mechanism of solidification of nodular cast iron by reproducing time-temperature curves of solidification of melts G3, G4, G4b and G5 with almost equivalent compositions.

These curves were drawn with the greatest of care, using a precise potentiometer. In the original plots, the temperature scale was 1.4 mm.

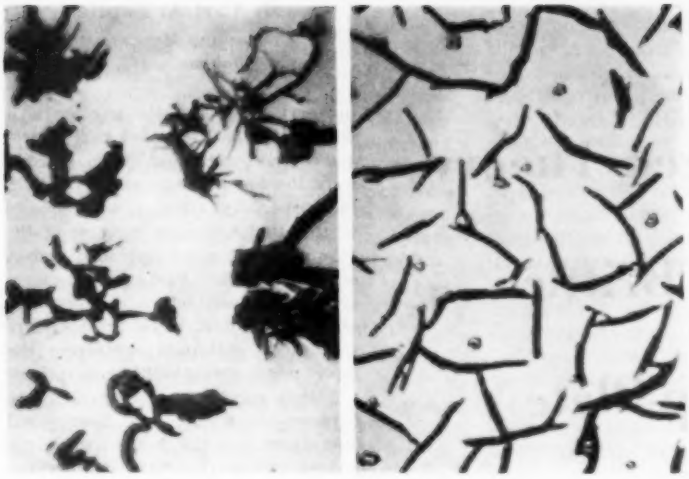


Fig. 6 and 7 — Bizarre Forms of Graphite in Magnesium-Treated Nodular Cast Iron, Dubbed Crabs and Forked Sticks, Respectively. 1000×

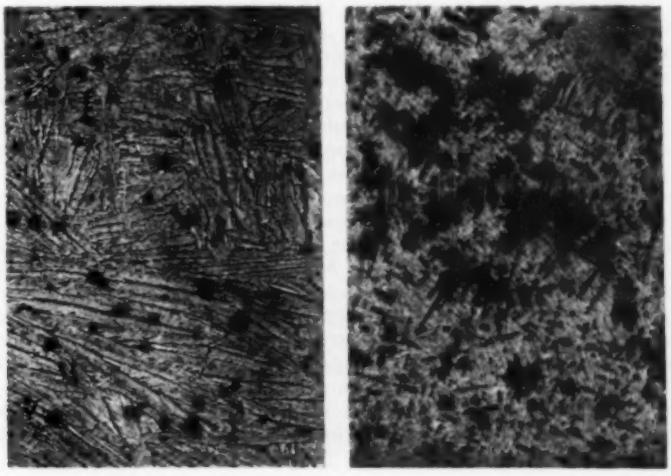
for 1° C. (½ in. for 10° C.) and 60 mm. (2.36 in.) for 1 min. They are shown, very much reduced in scale, in Fig. 8. It is important to note the very sharp arrest — even recalescence — in the curves for G5, G4, and G4b.

On the other hand the nodular cast iron G3 does not exhibit a recalescence, properly speaking; although the cooling rate is definitely slowed down when solidification starts, the curve still remains on the down-grade.

This fact is verified in all the cooling curves we have traced up to the present time in the laboratory; it should be added, however, that we have not made any great number of them, and that they all refer to magnesium-treated nodular cast iron.

In summary, it is our opinion that there is probably only one mechanism of formation of the graphite spherulites, but from our results we cannot conclude what actually happens. We only know that incorporation of minute percentages of strong deoxidizers like Mg, Ce, Li, Ba, Ca and Sr give the result, and that the solidification of as-cast nodular magnesium-treated iron corresponds to undercooling without any recalescence.

Fig. 8 (Left) — Magnesium-Treated Iron (Hypereutectic), Quenched Early in Solidification Yet Contains Spherulites. 150×. Fig. 9 (Right) — Same Iron After a Large Portion Had Solidified



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Hydrogen Theory for Brittle Ship-Plate

A CRISIS was precipitated in American steelmaking during World War I by a nationwide occurrence of the internal cracking defect now termed the "flake". Some two million of our men were in Europe at that time and yet little or no heavy forged steel equipment ever left these shores because of damage done by flakes.

For two decades thereafter, the subject of the nature and origin of flakes was hotly argued. It was particularly annoying at the time that this problem was more or less restricted to American steels, whereas European manufacturers were experiencing much less difficulty.

Is the problem of brittle ship-plate in World War II a relative of the problem with flakes in World War I?

Finally, in 1935, Houdremont and Korschan[1] (references will be found on p. 808) in Germany published the first rigorous definition of flakes and the conditions under which that defect occurs. They pointed to the fact that products of crucible and acid openhearth processes showed far less tendency toward flaking than did those of the basic process. This was significant evidence because Continental practice has always been primarily acid, whereas American practice is almost entirely basic.

Also in 1935, the German investigators Bennek, Schenck, and Müller[2] advanced the first proof that flakes are caused by hydrogen gas dissolved in the steel. Cramer contributed similar proof in America shortly thereafter.[3] The history of this worldwide study of flaking was reviewed by the author ten years ago;[4] today, the story is more or less common knowledge.

Flakes in World War II — In the intervening period between the two wars, it was gradually discovered that hydrogen embrittlement and internal stress[5] were the factors responsible for flaking, especially after it was demonstrated that hydrogen was one of the two necessary and cooperating causes of the defect. Perhaps the most generic of these factors, in a practical sense, was found to be the moisture content of materials contacting the liquid metal during melting operations.

Here was the key to the difference between American and Continental operations, for the basic openhearth process utilizes limestone and calcined lime which have a particularly high affinity for water. This means that American steel has always been disadvantageously exposed to moisture during the melting operation, and hence to hydrogen absorption. One of the most important contributions to the basic openhearth process in the past couple of decades has concerned precautions of drying the raw materials, particularly the burnt lime, prior to charging them into the furnace.

Principally as a result of such precautionary measures, the incidence of flaking in the course of producing steel for World War II was markedly decreased. Slow cooling was also adopted as a prominent countermeasure, for without an imposed stress from other sources, hydrogen can produce embrittlement but not cracking, which is the flake.

On the other hand, this unfortunately often placed ingots and blooms on the market which were *flake-free*, but *flake-sensitive* to any reheating and cooling operation — "flakeless but flakeable". An example will be cited where a certain forging shop lost an entire order of 600,000 lb. of special alloy steel because of flakes. The steelmaker could not be held because there was not a flake to be found in the ingots or blooms as supplied. Yet, every forging made from this steel developed flakes, and often in spite of slow-cooling operations extended for several weeks to reduce thermal stresses. The author saw one of these blooms cold-sawed. The effusing hydrogen gas caused his clothes to be spattered with saw lubricant though he stood five feet away from the cut.

This plant, and many others, eventually turned out sound forgings — but at a terrific cost of furnace or pit construction for slow cooling, and consequent delays that lasted sometimes as long as six weeks. All of this was caused by a "tramp" element in steelmaking which metallurgists have been astonishingly slow to include on their list of tramp elements. During the second war, losses in American plants occasionally were high because of hydrogen cracking, or flakes, but the problem was relatively small when compared with that of World War I.

Brittle Ship-Plate — However, in World War II a new and a more subtle problem arose to challenge American steelmaking. Its scope is well indicated by the nine papers, one being entitled "Brittle American Plate",[7] presented at the special *Conference on Brittle Fracture in Mild-Steel Plates*, held in October 1945, Cambridge, England.[6] E. M. MacCutcheon of the U. S. Coast Guard[8] bluntly states that the defection in question is a matter of an inferior quality of American steel. He is referring to the fact that out of 4700 ships built by welding methods in America during the war, 20% suffered structural failures, half of which were serious. More than 40 of the ships broke completely in two, often with loss of life. Admiral Cowart estimates the cost of this disastrous metallurgical problem at 50 million dollars.[9]

Once again, then, we have a serious difference apparently developing between Continental and American practices in steelmaking. This time it is not "flakes" *but the problem may be closely related to flaking*, having the nature of a sequel to the earlier difficulty.

The General Problem of Fracture

Principally under pressure from the United States Navy, acting through its Office of Naval Research, laboratories both in this country and abroad have vigorously pursued the problem of brittle ship-plate during the past several years. The work has been far too extensive to permit reviewing here; but it can be summarized very briefly as follows: *(a)* The problem has to do with a phenomenon in which the plastic mechanisms operative in ductile metal are replaced by elastic mechanisms, or brittle fracture, and *(b)* the fundamental cause of this phenomenon is not yet known.

Fractographic Pattern of "Toughness" — In September 1947, by order of the Bureau of Ships, Navy Department, specimens of nine "pedigreed" ship-plate steels were supplied the author's laboratory for fractographic examination. These steels were selected specimens which had been independently examined by a number of research laboratories using different test methods. Fractography had just previously disclosed a pattern indicative of toughness,[10] and it was desired to find whether a difference could be detected between steels that had a common analysis but were known to differ substantially in their fracture behavior. The success of the fractographic method was rather startling. Several of the patterns are reproduced here to illustrate the microscopic nature of the phenomenon in question.

Special attention is called to the fact that the first two fractographs shown refer to fracture in liquid nitrogen at −196° C. At this temperature all steels fracture in a brittle manner. The differences in pattern, therefore, express real structural differences of an extremely subtle type within the body of the individual grain itself; in turn, these must account for the contrasting fracture behaviors when, in higher temperature ranges, one steel behaves in a ductile manner and the other does not.

Figure 1 (p. 804) shows a fractograph for steel "Q". The magnification is 1250 ×, and the fracture has presumably progressed through the body of the grain. The important point to observe is that the fracture traverse has obviously been continuously interrupted, here showing as a roughened surface suggestive of coral in its pattern. Mechanical testing by other investigators has unanimously designated steel "Q" as one having a relatively low "transition temperature", hence a tough steel. This, then, is a pattern of "toughness".*

By way of contrast, a facet of steel "E" is shown in Fig. 2. Steel "Q" had been found to have a transition temperature in the range of 0° F., whereas steel "E" showed its transition ranging from 90° to as high as 150° F.[11] Accordingly, this is a steel of inferior toughness. That inferiority is illustrated in Fig. 2 by *(a)* the expansiveness of the field and *(b)* the relative flatness of the fracture traverse. In addition, some parallel markings of crystallographic origin are visible in Fig. 2, and these further characterize a steel which tends toward elastic behavior rather than plastic.

"Fractotropy" — Accordingly, the two fractographs shown in Fig. 1 and 2 prove that something, which metallurgists do not yet

*Actually, the water quenched condition of this steel is largely responsible for its preferred classification, but the fractographic pattern illustrates the fact of its toughness.

Fig. 1 — Fractograph for a Facet in Steel "Q", Revealing a Typical Pattern of Toughness and Referring to a Relatively Low Fractotropic Temperature. The course of the fracture in this steel has been continuously interrupted. Specimen fractured in liquid nitrogen at −196° C. 1250×

Fig. 2 — Fractograph of Steel "E", Exhibiting Pronounced Lack of Toughness in Contrast to the Pattern Shown in Fig. 1. This steel has a very high fractotropic temperature, and the elastic tendency is shown by the relatively flat fracture and the characteristic parallel crystallographic markings. Specimen fractured at −196° C. 850×

understand, goes on in the solid state and which is of sufficient influence to determine the success or the failure of the steel during service at ordinary temperatures. To repeat, the photographed specimens both broke in a brittle manner in the test at −196° C., but the different paths of the microfracture in the two cases identifies one steel as "brittle ship-plate".

As for the phenomenon of a loss of ductility at low temperature, that behavior is common for many metals and has been recognized for years. However, the problem becomes acute for welded steel plate on ships for two reasons: First, the temperature below which steel in general becomes brittle lies unfortunately close to that of possible weather conditions in service; second, a number of obscure factors readily raise this temperature limit, thereby greatly aggravating the threat of a brittle condition.

Currently, this temperature limit between ductile and brittle behavior is called the "transition temperature". However, that term is both confusing and inexact, confusing because of the concurrent use of *transition* for metallurgical descriptions of change of phase, and inexact because of its emphasis on *temperature* as the controlling factor for fracture behavior. Stress rate, stress dimensionalism, notch geometry, size and shape of the section, grain size, composition, microstructure — these and still other factors are now known to share with temperature the property of controlling fracture type. All of these are responsible for the lack of agreement on "transition temperature" values among investigators employing various test methods and for the spread of values within each individual investigation. This in turn is responsible for a temperature range and for rather arbitrary boundaries instead of a single value.

In its broad aspects, the phenomenon represents a change in fractological behavior of the solid, just as changes in rheological behavior are known to be affected by similar or corresponding factors. The word "fractotropy", then, specifically describes a condition of change in fracture type or behavior, being parallel in its derivation to "allotropy" which signifies a change in crystal structure. The problem at hand is, accordingly, one of identifying the fractotropic agent other than temperature that is primarily responsible for causing anomalous brittleness in ship-plate steel.

A Hydrogen Theory for Brittle Ship-Plate

Today, the effects of hydrogen in solid steel are sufficiently discussed and understood so that the gas should be included immediately on any list of factors known to cause fractotropic effects in steel. Hydrogen embrittlement, by its very definition, raises the fractotropic temperature of steel to a range above that of whatever test identifies the embrittlement. In addition to the direct effect of hydrogen, an equally important indirect effect on fracture can derive from the notching provided by any minute internal crack developing in hydrogenized zones, such as flakes and underbead cracking in welds. Such notches will persist after the hydrogen has vanished. Then there is the further possibility of a hydrogen content insufficient to register as embrittlement in certain mechanical testing, but nevertheless sufficient to cause brittle fracture under the particular service conditions of structural plate.

Supplementing the impelling analogy between flakes in World War I and brittle ship-plate in World War II, there are specific observations at hand which fall directly within the reasoning and predictions of a hydrogen theory.

Admiral K. K. Cowart,[9] in the latest release from the Ship Structure Committee, defines the brittle zone in welded plate as lying outside the austenitized zone, hence in unhardened metal, and states that postheating at 1100° F. practically eliminates the brittleness, with preheating at 400° F. affording slight improvement. This postheating treatment is exactly that found to be optimum for removing hydrogen from weld metal[12, 13] and is a recommendation familiar to anyone dealing with the effects of that gas. Preheating has a slightly beneficial effect by lowering the inherent hydrogen values of the plate, and by prolonging the subsequent cooling period to allow more weld-injected gas to escape. Although Cowart mentions carbide or nitride precipitation, with no consideration given hydrogen, the beneficial effects of his described heat treatments could only act in the direction of increasing the precipitation of either carbon, nitrogen or hydrogen. The two first named form solid phases, only the hydrogen precipitates as an escapable gas phase whose effects can be diminished by mild heating treatments. This sharp distinction in the two types of precipitates distinguishes their aging behavior.

As for the brittle zone lying beyond the austenitized zone, this is in accord with the known behavior of hydrogen in causing embrittlement in a zone of lesser solubility adjoining a zone of greater. This is observed in underbead cracking, where the damage is done in metal adjacent to the hydrogen-rich weld puddle, rather than in the weld metal itself; it possibly conforms with Sims' theory of hydrogen precipitation from austenite.[14]

Further evidence can be found which is similarly in keeping with these known effects of time and temperature on removing hydrogen from steel. Barr[7] reports that heating at 930° F. causes marked improvement, as does normalizing; he suspects that an aging reaction is involved. The fact that some investigators found the properties of the inferior "C" and "E" steels had improved after a year or more agrees exactly with the known slow recovery of hydrogenized steels aging at ordinary temperatures and also ties in with an indication of an improvement in ship-plate after lengthening periods of service. Sims[14] gives between two and six years as the time required at room temperature for complete recovery of ductility in a 4-in. plate of steel embrittled by hydrogen. His estimate conforms with observations for brittle ship-plate and with the fact that thicker plate from any one heat shows a higher fractotropic temperature.[15] Hydrogen contents are known to remain higher in thicker and less worked sections. In flaking, the factor of thickness is so important that below some minimum dimension the hydrogen loss is too great to permit cracking under the particular conditions of stress producing the flake.

Finally, the work of Bunn[16] on steel welds specifically proves that hydrogen raises their fractotropic temperature. Hydrogen is therefore a fractotropic factor, deserving a place with temperature, stress rate, and others, in any consideration of brittle fracture in steel, and particularly in welded steel.

Where the effects of this gas have been discussed before, it has usually been from a standpoint of embrittlement readily observable by ordinary room-temperature testing. Careful attention, however, must hereafter be paid to fractotropic effects of this gas which are of a more subtle order, not necessarily manifesting under all conditions of fracture. Reference is made to the planar-pressure theory of hydrogen embrittlement,[5, 17] whose derivation follows from experimental demonstrations that hydrogen precipitates along certain crystal planes within the grain, and under pressures exceeding the elastic limit of the steel when embrittlement is observed. This gas may also be present under pressures which fall short of causing

obvious embrittlement, but which contribute importantly to brittle behavior when operating in conjunction with other fractotropic factors. Only the relationship with temperature has received exploration to date. It may be exactly such relationships as those with stress rate, or notch design, that hold the answer to a major problem with ship-plate.

Fractographic Observations of Hydrogen

Particularly in view of Bunn's significant work, some remarks on fractographic registrations of hydrogen are warranted.

In a number of researches,[18, 19, 20] hydrogen has been proved to flatten increasingly the fracture path through the individual grain in the course of its causing embrittlement. In early stages, the effect provides a pattern such as shown in Fig. 2 rather than that of Fig. 1. Next, rectangulation develops as indicated in Fig. 3, followed by the occurrence of block-like voids (also visible in Fig. 3) that represents a final stage, apparently expressing small crystalline particles of metal which have been exploded away from the nascent cleavage face at the instant that fracture relieved the perpendicular component of the previously triaxial aerostatic compression. The fractographic characteristics of the presence of hydrogen, then, are *(a)* an expansive and relatively uninterrupted fracture traverse, *(b)* sharply rectangular markings, and *(c)* small block-like voids. These are coincidentally the characteristics of brittle fracture.

Hydrogen in Weld Metal — One of the outstanding developments in the field of arc welding steel in the past decade, and particularly since the close of the war, has been the "low-hydrogen" electrode. This electrode is the result of the identification of hydrogen as the primary cause of underbead cracking, "fisheyes", and a generally decreased ductility in welded steel.[12, 13, 14] Here again is a history paralleling that for flakes.

In the fractographs of Fig. 4 and 5, some consequences of the development of this electrode are illustrated. Each represents a weld fractured in liquid nitrogen at −196° C., hence completely brittle at time of fracture. The fractograph in Fig. 4 shows metal deposited from a cellulosic E6010 electrode according to earlier practice, whereas the metal in Fig. 5 was deposited from the recently developed "low-hydrogen" Type E6015 electrode. The path of fracture in the former is flat and relatively uninterrupted, the characteristics of a condition of inferior toughness; the traverse in Fig. 5 is distorted and has an appearance similar to that shown in Fig. 1 for tough metal. Metallurgical features of the two steels are virtually identical — composition, rate of cooling. The research from which this material is excerpted[20] reveals that hydrogen entering the weld metal is responsible for this tendency toward a clastic or brittle condition, and hence to inferior toughness. In other words, the exemplary conditions of Fig. 1 and 2 have been duplicated in welding practice simply by varying the hydrogenizing during laying of the bead.

In terms of fractotropy, the presence of hydrogen has raised the fractotropic temperature. This conclusion from the fractographic study confirms the work of Bunn[16] which was mentioned in a previous paragraph, and it specifically demonstrates the validity of a hydrogen theory for the current problem with anomalously brittle plate on welded steel ships.

Fig. 3 — Fracture Facet Within Single Grain of Armco Iron Showing Typical Registrations of Hydrogen Embrittlement. Specimen annealed at 1250° C. for 2 hr., furnace cooled, and embrittled with hydrogen by pickling in an acid solution. The gas precipitated within the body of the grain along finely spaced crystallographic planes, which are closely related to those active in plastic deformation, and the condition of embrittlement resulted in a marked rectangular pattern expressing this crystallographic precipitation. Note the 90° angularity. Fractured at room temperature. 300×

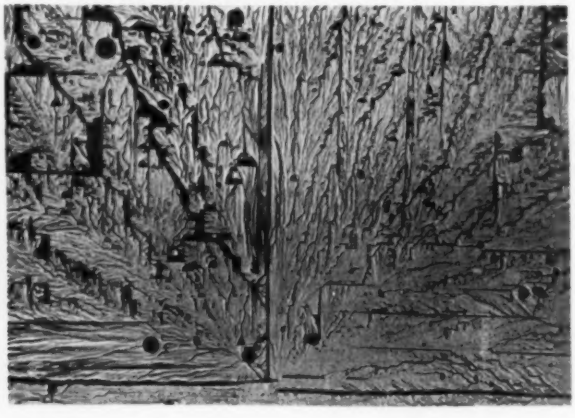

Fig. 4 — Fractograph Showing the Path of Fracture Through a Single Grain of E 6010 Weld Metal. This cellulosic electrode is known to provide relatively high hydrogen content in the weld metal, which is indicated by a flatness of facet similar to that shown in Fig. 2. Specimen fractured at —196° C. 575×

Fig. 5 — Fractograph of Weld Metal Deposited From E 6015 "Low-Hydrogen" Electrode. This electrode provides a low hydrogen content in the weld deposit; and the effect is illustrated as a rough cleavage traverse and a pattern of toughness similar to that shown in Fig. 1. Specimen fractured at —196° C. 575×

Summary

In summary, these are the following outstanding points to consider:

1. Hydrogen belongs on any list of fractotropic factors in steel, because hydrogen embrittlement, by definition, signifies a raising of the transition temperature to some value above the temperature of the particular test used to identify the embrittlement.

2. More subtle fractotropic effects of hydrogen in quantities subcritical for embrittlement, as commonly measured, are extremely likely, but remain virtually unstudied.

3. In addition to the obvious effect of measurable embrittlement and the possible further effects of subcritical hydrogen contents, enduring increases in transition temperature can be contributed to steel by hydrogen in the form of notch effects resulting from internal fissures such as flakes and underbead cracking.

4. The steel plate itself has a hydrogen history, indicated to involve especially high absorption in American basic openhearth practice, and that content will contribute both to increased elasticity of the plate itself and to an aggravation of any damage subsequently enjoined from welding operations.

5. "Brittle ship-plate", insofar as its occurrence is anomalous on the basis of present understanding,* can therefore be the result of any or all of the following factors: *(a)* hydrogen in the plate, *(b)* hydrogen in the weld, *(c)* a prior hydrogen fissuring action.

This, then, is a challenge to U. S. steelmaking. A similar challenge developed in the course of World War I with regard to flakes, and it was met and largely conquered. The present situation is believed to be an echo of the first, probably having to do with hydrogen contents which are less than those previously considered, and therefore more difficult to control.

However, the steel industry today is taking some vast strides by introducing changes in greater number and of greater scope than at almost any time since the development of the regenerating openhearth furnace. Present-day experimentation with such processes as the oxygen lance, for example, although primarily aimed at other steelmaking functions than reducing hydrogen content, holds excellent

*That is, the specimens in Fig. 1 and 2 differ a great deal in fracture behavior, but for known metallurgical reasons (heat treatment). Those in Fig. 4 and 5, on the other hand, are identical by common metallurgical definitions neglecting hydrogen content, whereupon the higher transition temperature of the hydrogen-rich metal constitutes an "anomaly" exactly as confronts metallurgy today in the principal problem of brittle ship-plate — the anomalously brittle behavior of steels which exhibit no other recognized distinctions from specimens of the same kind.

promise for exactly that action. Then again, a number of steelmakers are currently using other applications directly aimed at dehydrogenizing.

Whether hydrogen is an important factor or not in brittle ship-plate, that powerful and omnipresent constituent of steels remains largely uncontrolled today. Carbon, another powerful interstitially alloying element in steel, similarly ran wild and uncontrolled in the early history of stainless steel. However, the stainless steel industry not only expanded in virtually direct proportion to the carbon control it achieved, but this relationship still continues to express itself today in such developments as the ELC ("extra low carbon") austenitic grades which open new areas of service through virtual removal of the "tramp" element carbon.

Hydrogen, in alloyed and unalloyed steels alike, is more effective than carbon in certain respects, and those developments in steelmaking which will ultimately result in the control and eventual elimination of this gas can be awaited with great interest. Above all, in the interests of national security, effective dehydrogenizing procedures should be applied immediately to all heats marked for ship-plate.

As for welding procedures, it would seem to be patent as a future universal requirement in the welding of structural steel that only those electrodes be used which are designed to minimize hydrogen absorption, and that further precautions also be taken, such as postheating and/or preheating, to reduce the hydrogen content as may be required in order to avoid its deleterious effects.

Acknowledgment — The author is grateful to the Office of Naval Research for their sponsorship of a research in his laboratory on fractography under Task Order I, and on gases and metals under Task Order II, Contract 6-onr-258, results of both of these investigations being incorporated in the present paper. The assistance of M. E. Haslem, F. K. Landgraf, and C. O. Worden is also acknowledged.

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Casting-In of Inconel Tubes in Copper Blocks

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IT IS WELL KNOWN that successful separation of the uranium isotopes during the War was done at Oak Ridge by the electromagnetic method and by the diffusion process. The extensive plant for the first method carried Y-12 as a code name. It used the principle of the mass spectrograph. A beam of ionized uranium atoms was passed between flat poles of a very large magnet, and the magnetic field bent the atoms in semicircular paths. The heavy isotope U^{238} traveled a somewhat wider sweep than the light isotope U^{235}, and the two ended in different collectors. This process is used today at Oak Ridge for the separation of isotopes of nearly all the chemical elements, many of which are available to American scientists for experiments in numerous fields.

Obviously the generation of a parallel beam of ionized atoms is the beginning of this process. Furthermore, the easiest way to get some atoms is to evaporate the solid element (usually one of its compounds of appropriate melting point and vapor pressure). Accurately controlled and durable heaters are essential details of the equipment, and one good form is a copper casting which has embedded in it a heater similar in construction to the heating elements used in electric ranges. It consists of a nichrome filament centered in a welded Inconel tube and insulated from it by means of tamped magnesia. All too frequently these heaters have failed after only a short period.

The exact cause was an open circuit in the nichrome filament caused by local overheating. We believed that the overheating was due to voids (regions of low conductivity) between the tubing and the copper-tin casting. Many heaters from several different suppliers were radiographed and they contained large gas pockets around the heating element and throughout the casting itself. Figure 1 shows a radiograph of a typical casting; compare it with the sound casting shown in Fig. 2, which was produced in the Y-12 foundry.

This problem was studied with the following objectives:*

1. To determine the effect that heater position in the mold had on the casting.
2. To determine the kind of surface preparation of the Inconel tubing which would adhere best to the copper alloy casting.
3. To determine if seamless tubing yielded better castings than welded tubing.

Much of the work was done in the foundry of one of the vendors already supplying this type of cast heater. Simple rectangular castings were made containing Inconel heaters bent in the form of a W with rounded angles.

Influence of Casting Position

In order to determine if position in the dry sand mold had any effect, heaters were cast in a vertical position (end down), in a horizontal position (edge down) and in a flat position (face down). Three melts were made, and castings molded for pouring in all three positions were poured from each. All molds were preheated to about 450° F. Relative humidity in the foundry atmosphere was high — in the neighborhood of 90%. The furnace was a gas-fired pit type. The crucible was charged with alloy pig (1 to 2% Sn, 0.10% max. P, bal. Cu) and some gates and risers, then covered with charcoal.

*The document on which this article is based resulted from work performed for the U. S. Atomic Energy Commission by Carbide & Carbon Chemicals Division of Union Carbide and Carbon Corp., contractors for the operation of the Y-12 area.

Castings from the first heat, poured at 2100° F., were milled down to the center and gas pockets were observed in all of them (made in all three positions). The second and third heats were poured at 2150 and 2200° F., respectively. Just prior to pouring, 48 g. (1¾ oz.) of 15% phos-copper pellets was dropped into the crucible, and a few pellets (about 2.5 g.) in the risers of each mold just as soon as the metal came to the surface.

These castings were X-rayed. The radiographs proved satisfactorily that heaters cast in the flat position (face down) had fewer gas pockets around the Inconel tube than those cast in either of the other positions.

It is to be noted that Fig. 3 exhibits thermal cracks. This casting was the second to be made from Melt No. 3 and was poured at 2200° F. very gaseous, a condition the foundry superintendent was unable to explain. Melt No. 3 was apparently free from gas.

The next step was to determine the type of surface preparation for the Inconel tubing to produce the best castings. Accordingly, it was decided to make twelve castings in the vendor's foundry, all to be poured in the flat position previously found to be best. Three each were to be made with the following four methods of surface preparation suggested by different manufacturers of this type of casting:

1. Acid pickle
2. Sandblasting followed by a CCl_4 wash
3. Chromium plate
4. Copper plate over chromium plate

The acid pickle was recommended by the International Nickel Co., and consisted of 1000

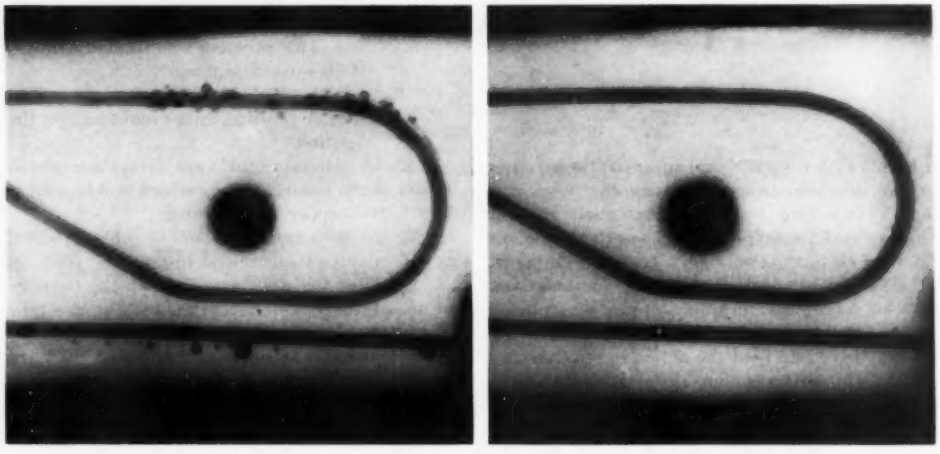

Fig. 1 (Left) — Radiograph of Heater Casting Containing Many Gas Pockets Around Cast-In Element; Fig. 2 (Right) — Sound Casting Made in Y-12's Foundry

The first four castings poured from this melt contained thermal cracks, while the last two showed none. The castings made from the first two melts (cast at 2100 and 2150°) contained no thermal cracks. It was deduced that thermal cracks appeared in this type of casting (heater in mold) when the pouring temperature was over 2150° F. The last two castings from Melt No. 3 (initial pouring temperature of 2200° F.) were also free of thermal cracks, probably because the molten alloy had cooled below 2150° F.

This hypothesis has been confirmed by the fact that a number of sound castings have been poured at temperatures lower than 2150° F.

All castings from melts No. 1 and 2 were

ml. of water, 1000 ml. of concentrated HNO_3, and 150 ml. of 48% HF. The heaters were bent to the desired shape, then annealed at 1900° F. for 20 min. When they had cooled, rubber caps were placed on the open ends and the heaters were immersed in the pickling solution for 10 to 15 min. at room temperature. They were then washed in warm water and examined for any remaining oxide scale; this was cleaned off with sandpaper and the heaters were washed in CCl_4. They were dried by heating in a furnace at 550° F. for 1 hr.

The plated heaters were pickled as above before plating in the Y-12 shop, standard procedures being employed.

Again three heats were melted, and heaters with each of the above finishes cast in. The charge consisted of 175 lb. with varying amounts of pig and risers ranging from 35% pig to 80% pig; 7 oz. of phos-copper was added to each. Molds were heated to 450° F., as before, and the atmosphere had a relative humidity of 75%.

Heat No. 1 was removed from the furnace at 2120° F.; since the charge showed considerable turbulence it was left to set until this subsided. Pouring started at 2020° F. and took about 7 min.

Heats No. 2 and 3 were poured at 1950° F. The latter was still turbulent at pouring temperature and was very close to solidification.

Radiographs of the finished castings showed that the acid pickled and chromium-plated heaters were best. No decision could be made as to which was the better, but they did show

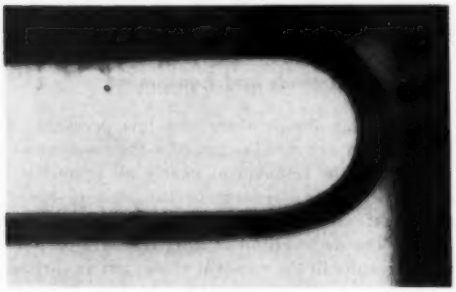

Fig. 3 — Thermal Cracks in Otherwise Sound Casting, Poured Flat at 2200° F.

their definite superiority over the sandblasted or copper-over-chromium plated heaters.

Gassy metal was evident in two of the three melts poured by the vendor. Accordingly, we made some experimental casts of this high-copper alloy in the Y-12 foundry to find the cause and methods to eliminate it. The furnace in the Y-12 foundry was of the same type as previously used, except that it was oil-fired. The required composition was obtained by adding tin shot to molten electrolytic copper. The same casting procedure was used in the first few melts, and included 2 oz. of 10% phos-copper to 100 lb. of metal cooled to 2150° F., just prior to pouring. These first few melts were very gaseous. Varying the amount of phos-copper was found to have no effect. Finally, the furnace pit was constricted by building in an extra lining; the charcoal covered crucible was also provided with a ceramic lid. These improvements produced gas-free melts more consistently than any other method tried. However, induction melting might prove more reliable.

Once we learned how to melt gas-free metal, six castings with acid-pickled and six with chromium-plated heaters were made as planned. Radiographs showed no difference resulting from the different surface preparation of the Inconel tubing. Acid pickling therefore has been used for subsequent heaters.

All of the heaters described so far were fabricated with welded Inconel tubing. Some hairpin-shaped heaters from welded and from seamless tubing were cast side by side. Six castings of this type were made, and in each the seamless tubes were surrounded by fewer gas pockets than the welded tubes.

Conclusions

The following conclusions can be drawn from these experiments:

1. Heaters lying in the flat position in the mold give better castings than heaters lying in other positions. The molten metal covers the heaters quickly, thereby lessening the chance that oxide can form on the sheath.

2. Correct surface preparation of the tubing is a contributing factor for the production of sound castings. Acid pickling proved to be the best finish. Possibly gas pockets around pickled tubing are due to hydrogen from the pickling bath. Therefore the heaters should remain in the acid as short a time as possible, and any remaining oxide or scale be removed with emery cloth.

3. Water vapor condensing on the heater after the preheated mold is removed from the core oven is also a factor to deal with.

4. Seamless pickled heaters give somewhat better castings than welded tubes, possibly due to dirt particles entrapped around the weld and which are difficult to remove by pickling or sandpapering.

5. Gas-free melts are essential for this type of casting. Every furnace and foundry has its own peculiarities, so that proper conditions in one would not necessarily apply to another. Consequently, if castings prove to be gaseous, furnace conditions must be adjusted until good melts are consistently obtained. The use of an electrical induction furnace rather than a gas or oil-fired furnace is recommended.

6. Since the metal must be poured below 2150° F. and solidification occurs about 1900° F., gating of the casting must be so arranged as to fill the mold completely with metal before solidification begins.

Forgeable Arc-Melted Tungsten*

By Harry B. Goodwin
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and Charles T. Greenidge
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TUNGSTEN is of special interest for use at high temperatures because its melting point of 6170° F. is highest of any metal. However, due to this high melting point, there is no refractory suitable for containing molten tungsten. Powder-metallurgy methods, therefore, are used to consolidate tungsten powder into bars suitable for hot working to sheet, wire, or other useful shapes. The successful development of ductile powder-metallurgy tungsten by Dr. W. D. Coolidge in 1909 is a fascinating story which has been well reviewed by S. L. Hoyt in his article "Ductile Tungsten", *Metals and Alloys*, January 1935.

Numerous attempts have been made to handle tungsten by melting methods, among the earliest being those described by Moissan in "The Electric Furnace" published in Berlin in 1897. Weiss, Martin and Stimmelmayer ("Über das Wolframmetall", *Zeitschrift fur anorganische Chemie*, Vol. 65, 1909, p. 323-340) melted tungsten with the arc in various atmospheres and in vacuum, using both carbon and tungsten electrodes. They claim cold ductility and forgeability for small globules of the metal. Other investigators have since successfully melted tungsten, but forgeable ingots of useful size and shape have not yet been produced.

Recently, at Battelle Memorial Institute,† tungsten has been successfully arc melted in vacuum to form a small forgeable ingot. The technique used was similar to that used to melt molybdenum. It consisted of arc melting in a water-cooled crucible which also acted as the ingot mold. This method eliminates the troublesome refractory problem, because with water-cooled crucibles an outer "skin" of the metal being melted freezes so that, in effect, a metal can be melted in a container of the same composition as the metal itself.

In practice, an ingot was built up gradually by continually adding melting stock; only a small fraction of the metal at the top of the ingot is molten at any one time. A consumable tungsten electrode was used, the entire melting charge being furnished by the melting of this electrode. The electrode used was commercial tungsten rod which had been formed by powder-metallurgy methods. Melting was carried out at a pressure of about ½ micron.

Methods and Equipment

The high temperature and low pressure of the vacuum arc-melting process thermodynamically favor the removal of nearly all impurities, since the vapor pressure of tungsten is lower than that of all other elements at its melting point. The deoxidation of tungsten with carbon, which results in the removal of oxygen as carbon monoxide, is also favored under these conditions.

For molybdenum, which is similar to tungsten in some ways (both are body-centered cubic, both are transition elements in the periodic table, they are in the same group in the periodic table, and the chemistry of their oxides is similar), an oxygen content of less than 0.0025% is necessary for the cast metal to be hot workable. (The tolerance for oxygen is somewhat higher for powder-metallurgy molybdenum.) The success of the vacuum arc-melting technique in producing molybdenum of this purity lent additional encouragement that the method might work for tungsten. It may be mentioned that earlier attempts at Battelle to arc melt both

*Grateful acknowledgment is made to The Rand Corporation and the Air Force for their permission to publish this information.

†Work conducted on a subcontract under Prime Contract AF 33(038)-6413, Project RAND.

tungsten and molybdenum in water-cooled copper crucibles under argon gas rather than vacuum did not produce forgeable ingots.*

For the experiments in vacuum arc-melting of tungsten, a ½-in. diameter tungsten rod 8½ in. long was used as the consumable electrode. This was brazed to the end of a water-cooled copper electrode extension. Since it was believed that the commercial rod contained sufficient carbon for the removal of oxygen, no carbon or other deoxidizer was added. The electrode was melted with an alternating current of 1200 amp. at 22 to 24 volts in a 1⅜-in. i.d. water-cooled copper crucible lined with a sheet of 0.010-in. molybdenum. The use of a molybdenum liner in the crucible rather than tungsten was simply a matter of convenience, it being much easier to bend molybdenum sheet to a small radius. Contamination from this source did not appear to be a serious matter.

The furnace used for the tungsten melting experiments is the same furnace which is being used for molybdenum research. This furnace was designed under the supervision of Robert M. Parke, especially for the molybdenum work. The furnace does not embody the feature of equipment at Climax Molybdenum Co. for continuous formation of a consumable electrode from metal powders, even though the Battelle (U. S. Navy) furnace was designed later. It was felt that the continuous electrode formation was really a production feature, and that for laboratory scale work consumable electrodes could as readily be formed in a separate operation. However, any alloy which can be made in our furnace could also be made by the Climax process, providing that the pressed powder possessed sufficient green strength so that the electrode rod would not break prior to sintering in the continuous process. Experience with powder-metallurgy tungsten would suggest that it does possess the necessary green strength.

The ingot formed was bright and was deeply cupped, with a rim of tungsten about 1 in. high around the sides of the crucible. It was well melted, with a solid and sound portion about ¾ in. high. The surface was quite good but was probably slightly contaminated with molybdenum, as the surface of the molybdenum liner showed signs of having melted in places.

*Both the consumable-electrode technique and the water-cooled inert-electrode technique have been used successfully to arc melt molybdenum in vacuum. The former was originally developed at Climax Molybdenum Co., the latter at Battelle. Alternating current is used in both cases. In the Climax process, the electrode is formed continuously.

Forgeability of Tungsten

A cylinder $\frac{9}{16}$ in. thick by 1¼ in. in diameter was cut from the solid portion of the ingot and ground smooth. This cylinder was heated to 2800° F. for ½ hr. No protective atmosphere was used in this furnace. The hot tungsten cylinder was flattened into a pancake with a forging hammer. It was forged four times, using two to three hammer blows each time, and was reheated to 2800° F. for 10 min. between each forging. On the last forging, some edge cracking developed. The thickness of the cylinder was reduced from $\frac{9}{16}$ to $\frac{3}{16}$ in. and the diameter increased from 1¼ to 1¾ in. The ingot appeared to forge easily and without using particularly hard blows of the hammer. A thin yellow film of oxide formed on the surface.

Figure 1 is a photomicrograph of the tungsten bar after forging. It will be seen that the metal is exceptionally clean. No oxides or carbides are present. The very large grains, oriented

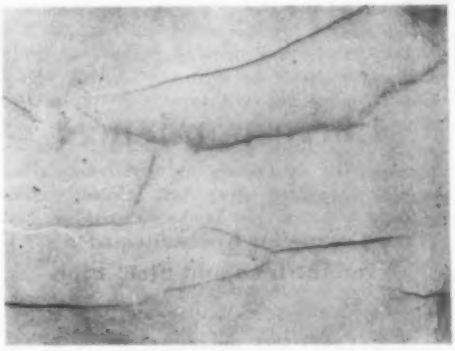


Fig. 1 — Microstructure of Tungsten Ingot (After Forging) Shows Metal Free of Oxides and Carbides. Etchant, picral; magnification 40×

in the manner typical of arc-cast metal, have been flattened out somewhat by the forging. A fractograph of the forged pancake showed that its fracture is predominantly transcrystalline. No second phase is evident at the grain boundaries of the few grains in which intergranular fracture occurred.

The micrographic and fractographic results suggest that the reason for the improvement in forgeability of this ingot over previous samples of cast tungsten is its increased purity. This reasoning is supported by the analogous experience with other metals. Molybdenum, tantalum, titanium, and zirconium were once believed too

lacking in malleability to be worked and were proved to be malleable when sufficiently purified.

The forging of this ingot suggests that, by using swaging or a less severe type of forging and by grinding out edge cracks as they appear, working of the metal could be carried as far as desired.

The importance of this finding is that melting methods often produce metal of quality superior to that produced by powder metallurgy, and melting methods are usually cheaper for large shapes. A much smaller press is required to form consumable electrodes for preparing a large ingot by melting than would be required to form the same size of ingot directly by powder metallurgy.

The significance of this experiment, we believe, is that it has shown arc melted tungsten to be forgeable. So far as we know, this has not been demonstrated before. Thus, our work would infer that, under the proper conditions, forgeable tungsten ingots could be prepared by the Climax process that is now being used for molybdenum.

This would mean that we would be freed of the size limitations imposed on "ingots" made by the powder-metallurgy process by the necessity of using large and costly presses and by the flow characteristics of metal powder. The real value of the finding, therefore, is that it might lead to larger useful tungsten shapes — possibly at lower cost.

Whether larger pieces of tungsten would have practical uses is another matter, but the question is no longer academic now that it seems to be possible to prepare them.

Correspondence

Corrosion Resistance of Wrought Iron and Steel Pipe

MILWAUKEE, WIS.

S. L. Case's very interesting article on the "Corrosion Resistance of Wrought Iron and Steel Pipe" in the March issue of *Metal Progress* covers a thorough survey of this subject. We have had considerable interest in the over-all comparisons of the materials cited, with particular reference to a low-metalloid basic open-hearth iron which has found some favorable usage as tube. It may be of interest to readers of Mr. Case's article to give some previously unpublished data — admittedly meager and covering relatively short exposures in atmospheres, slightly over one year — a period questionable as to real value in atmospheric study. However, since the two tests of 400 and 460 days, respectively, gave comparable results (wrought iron was included only in the second exposure), the data are of some interest. These data also substantiate our general opinion that low-metalloid ingot iron is a practical equivalent of wrought iron, and that ¼% copper added to this low-metalloid iron improves the atmospheric corrosion resistance.

While the tabulated data indicate that all the grades tested are slightly better than low-

Corrosion Loss in Industrial and Residential Atmospheres*

METAL	CHEMICAL ANALYSIS						1ST TEST		2ND TEST	
	C	MN	P	S	SI	CU	IND. ATM.	RES. ATM.	IND. ATM.	RES. ATM.
Low-carbon steel	0.074	0.46	0.010	0.028	0.11	0.04	5.12*	3.65*	5.59*	3.69*
Low-carbon steel plus copper	0.10	0.48	0.014	0.035	0.06	0.25	3.26	2.08	3.04	2.56
Low-metalloid iron	0.046	0.20	0.021	0.024	0.01	0.03	3.89	3.15	4.04	2.81
Low-metalloid iron plus copper	0.032	0.18	0.012	0.013	0.06	0.31	3.20	1.86	2.51	2.17
Wrought iron pipe†	—	—	—	—	—	—	—	—	3.98	2.58

*Loss is % of original weight. †Commercial pipe, analysis not determined.

carbon steel, we are fully aware that only single heats were evaluated under limited conditions. Mr. Case's comments pointing out large variations in individual heats of the same grade should not be overlooked.

As a matter of record, the tests were made in the Milwaukee area, one within our plant area (industrial atmosphere); the other in a residential neighborhood close to Lake Michigan (residential atmosphere). The loss in weight was determined after carefully removing scale by pickling, using an inhibitor to prevent attack on the metal underneath.

ELMER GAMMETER
Director of Laboratories
Globe Steel Tubes Co.

Partial Stabilization of Stainless Steels

NIAGARA FALLS, N. Y.

It was most excellent to present the various viewpoints on "Conservation of Columbium" in last November's issue of *Metal Progress*, since much was brought out, and it also showed the gaps that exist in information.

In that series of articles, D. C. Buck, under his Item 5, mentions the desirability of testing stabilized and unstabilized grades under actual service conditions. He further recommends that tests should be made in steels containing variable quantities of titanium and columbium. Since such testing is time-consuming and laborious, I should like to offer some comments that may save some time. *Partially* stabilized compositions are of doubtful value; Mr. Buck did not necessarily intend to include this field in his comments, although this particular notion can be obtained therefrom.

At one time, we had the idea that it might be more economical to melt 18-8 to 0.15% carbon specification and stabilize part of that carbon with titanium rather than melt to the customary 0.07 maximum carbon. To this end, we made a laboratory heat of 0.07% C, 1.31% Mn, 0.25% Si, 17.30% Cr and 10.23% Ni, poured out a portion and raised the carbon content of the remainder to 0.16% by the addition of a carbon spiegel, poured out another increment and, to the metal remaining in the furnace, added sufficient titanium to just about stabilize its carbon above 0.07%. The small ingots were forged, annealed at 1950° F., then heated 2 hr. at 1250° F. and air cooled. The analyses of these heats and the result of bend test after 100 hr. in modified Strauss solution are as follows:

C	Ti	Bend Test
0.07	0.0	Orange peel and fine cracks
0.16	0.0	Cracked completely
0.13	0.31	Cracked completely

These tests show that the desired objective was not attained. My interpretation is that, in the 18-8 base composition and the carbon ranges as above, there are formed complex carbides which are certainly different from titanium carbide. This may not at all hold for partial stabilization of melts containing, let's say, 0.07% maximum carbon. These tests do show, however, that though we have definite proof that titanium certainly does form titanium carbide in low-alloy steels regardless of the carbon content, this cannot be stated for an alloy containing 18% chromium. Furthermore, I am willing to predict that, for the carbon range in the tests cited above, similar conditions will prevail if one resorts to partial stabilization with columbium.

As stated originally, the purpose of these comments is to indicate that partial stabilization may not be attained if one desires a steel whose behavior is to be half-way between Type 302 or 304 and the fully stabilized grades. In making this statement, I do not mean to imply that, in all types of service, one must *a priori* employ stabilized grades, because there are some experiences in chemical environments which indicate that fully sensitized, regular 18-8 performs as adequately as the columbium or the titanium stabilized grades.

STEPHEN F. URBAN
Director of Research
Titanium Alloy Mfg. Division
National Lead Co.

Small Watch Parts

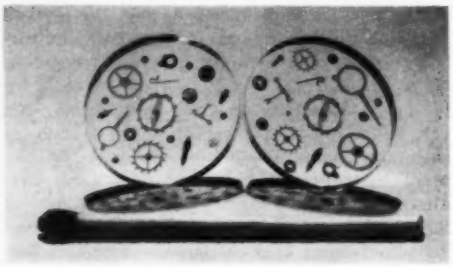
LANCASTER, PA.

On receipt of *Metal Progress* for March 1951 I was particularly interested in the cover design by Clifford A. Guc, and I was intrigued by his artistic rendition of what we call an in-line watch gear train. Possibly in the artist's travels he may have seen one of these in-line movements which we send to jewelers in connection with some of our advertising efforts.

So that you may have readily available exact samples of some of the gears represented in Mr. Guc's cover, I am enclosing two pocket pieces, in which the watch parts are mounted in lucite.

The small flat wheels used in the train of a

watch are generally made of brass. Some of the flat steel pieces which require greater rigidity — such as the regulator and escape wheel — are made of flat steel strip. All of the screws used in Hamilton watches are made of stainless steel (Type 420-F), and we are currently engaged



Watch Parts, Full Size, Mounted in Lucite. The speck at left center of right disk is a set screw

in a program of manufacturing other watch parts of stainless steel. However, at the present time, most of the staffs and pinions are made of plain high-carbon steel.

The jeweled bearings are made of artificial corundum (sapphire), and the jeweled bearings for mounting them in the watch plates are generally surrounded by a metallic circle or mounting of either brass or low carat gold. The metallic mounting adds strength to the jewel, which is very brittle.

G. E. Shubrooks
Chief Chemist & Metallurgist
Hamilton Watch Co.

Titanium Resists Stress Corrosion

Cambridge, Mass.

In a recent study on the corrosion behavior of titanium, we considered it of interest to know whether this metal is susceptible to stress corrosion cracking in boiling saturated magnesium chloride and also in 10% sodium hydroxide. Magnesium chloride, for example, is active in causing stress corrosion cracking of austenitic 18-8 stainless steels and is used in accelerated tests. Austenitic stainless steels have also been reported to stress crack in certain concentrations of hot sodium hydroxide.

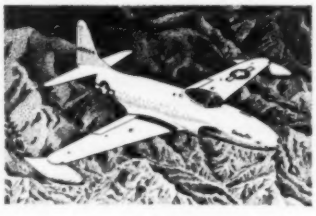
We used titanium sheet 0.035 in. thick supplied by the U. S. Bureau of Mines. These were cut into ⅜ x 5-in. specimens, bent beyond the elastic limit into the form of a U, and held in this position by notched holders cut from the same sheet as the specimens. A specimen was then totally immersed in boiling saturated magnesium chloride contained in a 1-l. Erlenmeyer flask fitted with a thimble-type condenser. Another specimen in a second flask was arranged similarly as duplicate. In addition, two specimens of 18-8 Type 304 were set up identically for comparison.

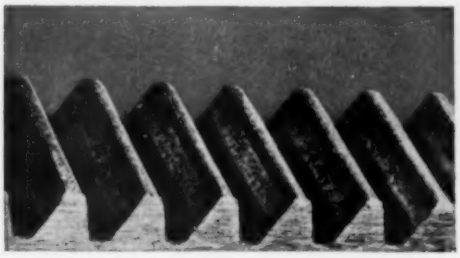
Within four hours, the two 18-8 specimens cracked at the region of maximum bending. The titanium specimens, on the other hand, were still not cracked when the test was discontinued after 62 days, and (except for a shallow pit on only one of the specimens) the visible corrosion was slight.

Two specimens of each metal were prepared similarly for tests in boiling 10% sodium hydroxide solution. The container was fabricated, of necessity, from nickel sheet instead of glass — welded cylinders, 15 in. long and 3 in. in diameter, with a loose-fitting nickel cover. Copper coils were soldered on the upper outside surface through which water circulated, thereby acting as a condenser. Specimens were suspended by a narrow width of metal of the same composition as the specimen, and protected from galvanic contact with the nickel container walls by a sheet of "Saran".

At the end of 28 days, neither the titanium nor the 18-8 cracked. The titanium was corroded only slightly; weight loss was computed at 1.5 m.d.d. (mg. per sq.dm. per day), and the surface was slightly tarnished. On the other hand, the 18-8 turned black, but nevertheless corroded on the order of only 15 m.d.d. Presumably it would have cracked had both the temperature and concentration of sodium hydroxide been higher, such as is achieved in the bomb described by Messrs. Huseby and Scheil in *Transactions* of the Association of Paper and Pulp Industry for March 1950. Whether or not titanium would crack under more severe conditions is not known.

H. H. Uhlig and J. R. Cobb, Jr.
Corrosion Laboratory
Massachusetts Institute of Technology





This forged steel gear rack shows severe wear and pitting. The rack was made from free-machining, medium carbon, resulfurized manganese steel, corresponding in composition approximately to the A.I.S.I. C-1137 type. It was used as-forged, with a hardness of 200 Brinell, to operate against a gear made from sintered high carbon steel, copper-impregnated, with a tensile strength of 85,000 p.s.i.

This ductile iron rack, produced by The Acme Shear Company, Bridgeport 1, Conn., showed no pitting . . . after exactly the same service test as the steel rack. The only evidence of wear is a burnished appearance on edges of the teeth. This ductile iron rack had a hardness of 205 Brinell, but any hardness within the range of 150/200 proves satisfactory under similar conditions. Saving in cost is estimated at 60%, based on the low initial cost of ductile iron, and its superior machinability.

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Microstructure of Titanium

By H. P. Roth

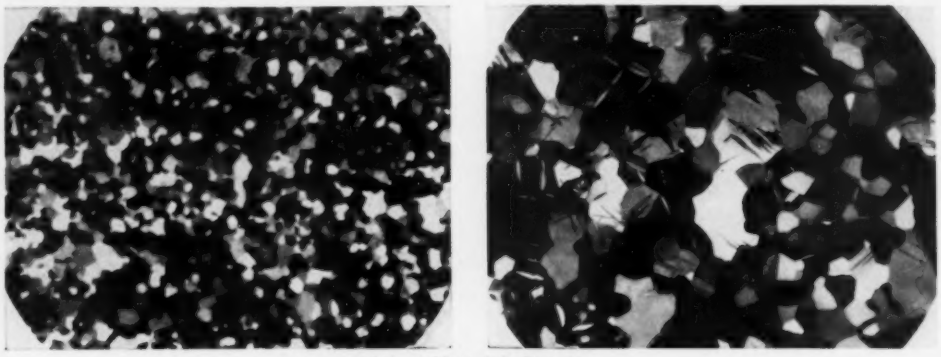
Close-packed hexagonal metals respond beautifully to electropolishing and to examination by polarized light. The companion elements titanium, zirconium and hafnium are alike in this respect, as is also orthorhombic uranium. (Beryllium presents more difficulties in removing sufficient metal without pitting and in the duplication of results.)

Jacquet's electrolyte for titanium (equally good for worked metal) was used: 100 parts of glacial acetic acid plus 6 parts perchloric (sp.gr. 1.54).

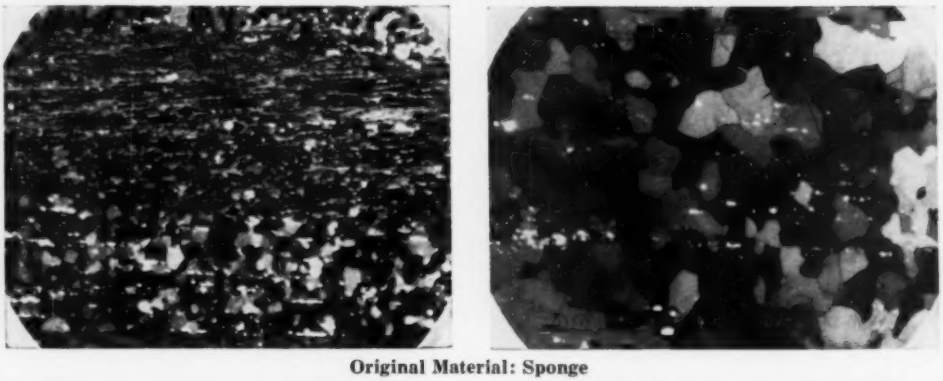
These specimens are viewed directly at 100× by polarized light without further etching.

Samples as Extruded

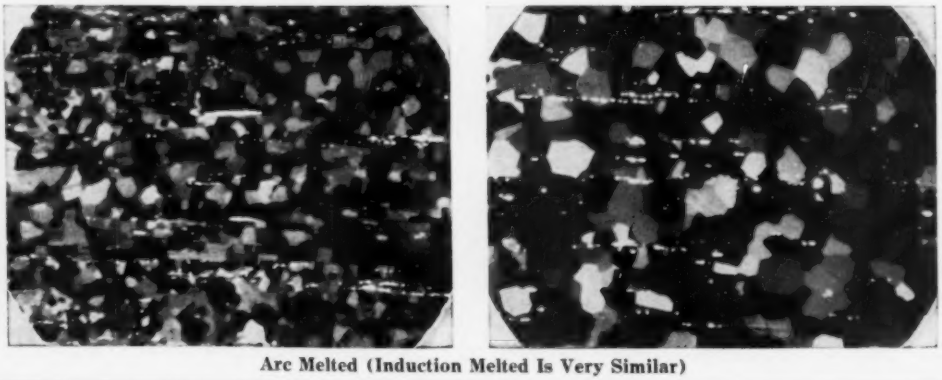
Samples Annealed at 900° C.



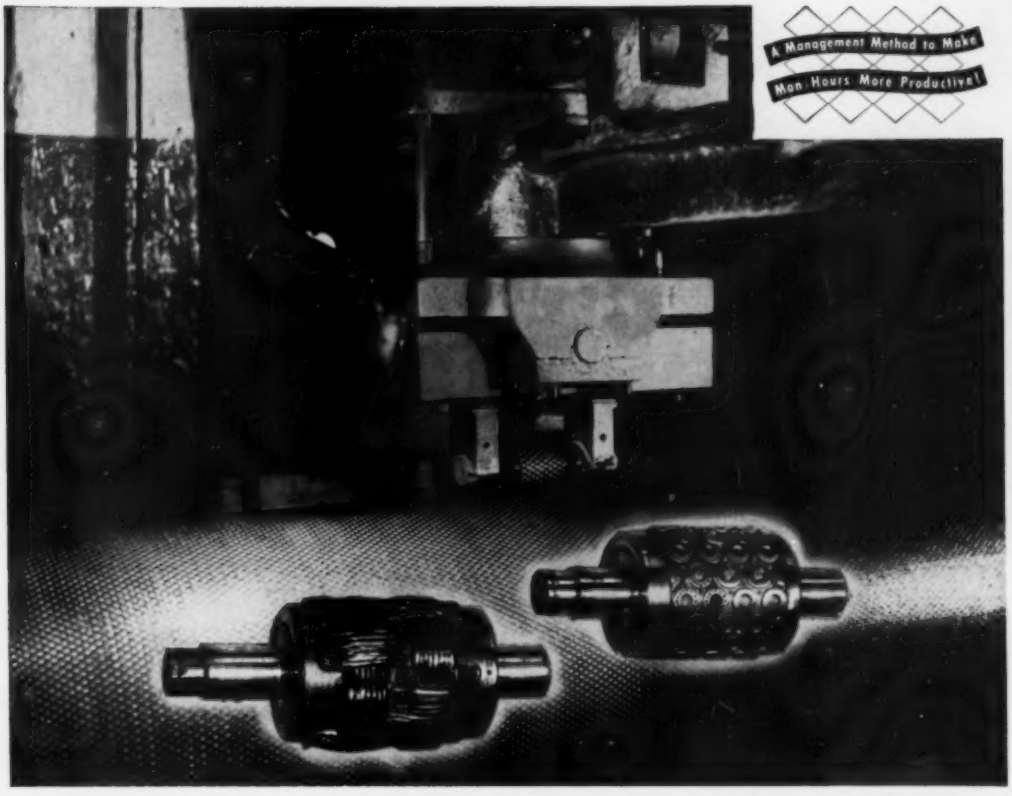
Original Material: Powder



Original Material: Sponge



Arc Melted (Induction Melted Is Very Similar)



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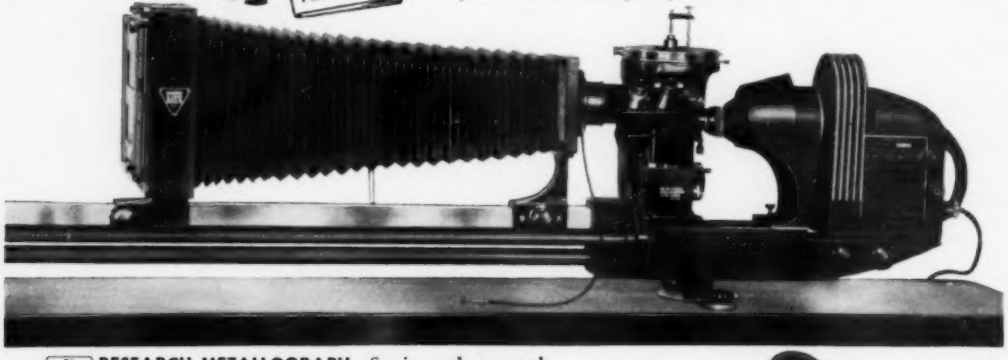

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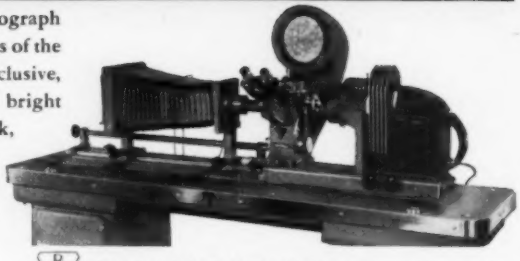

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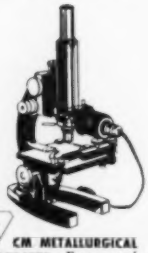

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One of the
Panel Discussions
at Western Metal Congress
Oakland, Calif.
March 21, 1951

Saving Precious Alloys by Intelligent Use of Alternatives

AFTER introducing the panel members, the Moderator (Ernest E. Thum, Editor of *Metal Progress*) remarked that the morning's panel discussion on strategic nonferrous metals developed the fact that the best cure for a shortage is to get a larger supply. "The American metallurgical industry is better equipped to do just that than any other group in the world. However, before we can get more iron and steel we certainly must provide the raw materials, and the principal raw material is ore. Unfortunately we have gone through a couple of world wars and we have scooped up a great proportion of our readily available high-grade iron ore in the Great Lakes region. Dr. Austin, could you give us some ideas as to what the future is going to hold?"

JAMES B. AUSTIN (director, U. S. Steel Co. Research Laboratory, Kearny, N. J.; panel member) — The ore is going to come in two ways — first, through beneficiation of taconites in the Lake Superior region, and second, through the importation of foreign ores. There is a nice economic balance; taconite concentration plants are very expensive, and you can't afford too many if you have alternative sources of iron. It may be cheaper to bring ore from Canada, Labrador, Venezuela (or wherever you find it) to some blast furnace plants in America than it is to work the taconites. On the other hand, we simply cannot be dependent on foreign sources of ore. So we should beneficiate the taconites up in Minnesota, and that problem is being attacked. Probably within five years there will be substantial tonnages of concentrates coming off the range.

THUM — Could the added cost of pelletized concentrate be recovered in improved blast furnace operations?

AUSTIN — We certainly hope that the benefits derived from a more concentrated raw material (so that you get a greater output) and from easier operation of the furnace with the uniform charge will meet much of the increased cost.

THUM — Has anyone on this panel any information concerning the iron ore resources of the western states. At the present time about 5% of our steel is being made in this region. What is your estimate, Fred?

FRED J. ROBBINS (president, Sierra Drawn Steel Corp., Los Angeles; panel member) — I have very little direct information. Two good sources would be the Kaiser Co., Inc., of Fontana, Calif., and Geneva Steel Co., of Geneva, Utah. I believe the deposits in southwestern Utah, which both rely upon, have about 250,000,000 tons of probable ore carrying 50% iron. Kaiser's furnaces are now drawing much ore from two mines in California, much nearer Fontana, estimated to contain about 25,000,000 tons of somewhat richer ore. The total is hardly equal to two years' demands of the entire American industry although it appears to be a comfortable supply for the western industry. Lack of coking coal nearer than northeastern Utah is a serious handicap to blast furnaces on the coast. Also, the West Coast has always been a large scrap melting area, and the present shortage has a big bearing on this over-all picture.

THUM — The foreign ore supply is hooked up with the plant expansion program in America. We have capacity for about 100,000,000 tons of ingots right now, and that requires about

Pinch in alloys likely to be worse than in the 1940's—Jominy

140,000,000 tons of ore. A very sizable expansion is underway in steelmaking plants, and this will take even more ore. Dr. Austin's company, United States Steel, has announced plans for a large integrated plant on the Delaware River near Trenton. Where will the ore for that plant come from?

AUSTIN — That plant is designed with Venezuelan ore in mind.

THUM — Have you any comment to make on the supposition that strategically important industry should be far inland where a submarine can't lob an atomic bomb on it?

AUSTIN — There has been so much discussion in Washington on that subject I don't think there need be any more in San Francisco.

THUM — Those in established iron and steel regions hardly like to see foreign ores draw the plants away.

AUSTIN — Of course, there is a little matter of markets on the East Coast — markets and freight rates.

THUM — That probably is the reason there is not more steel made in Pueblo, Geneva and on the Pacific Coast where there is seemingly an abundance of good ore. As far as the more intensive use of our present plant is concerned, I wonder would anyone on the panel comment on such things as pressurized blast furnaces or the use of oxygen to speed up refining.

JOHN CHIPMAN (director of metallurgical department, Massachusetts Institute of Technology, Cambridge; panel member) — We hear some very enthusiastic reports on the pressurized blast furnace operation from the Republic Steel Corp. The principles are pretty sound and well worked out and it offers a means of increasing the output of a modern furnace of a given size by producing a higher concentration of reducing gases within the furnace. If you increase the pressure on a gas you make it more concentrated, more dense. For example, the number of contacts per second between iron ore and reducing gas molecules is doubled if you double the pressure. More reducing gas is put through the furnace with increased pressure, and therein lies its chief virtue.

THUM — How about enriching the blast in oxygen?

CHIPMAN — I don't know the results of the current experiments, but based on the German experience I would guess that our experience would come very close to theirs. There seems to be relatively little hope that oxygen enrichment will do much in a furnace that is producing basic iron and which is already being well run. If it's in trouble, then probably oxygen will do something for it; if it isn't in trouble, then maybe it is likely to make it a sick furnace. On the other hand, I think there is a much better chance for oxygen enrichment in ferro-alloy furnaces, and only time will tell what benefit we can get from that.

THUM — I take it, then, that our panel feels that as far as raw materials are concerned America has sufficient ore — or rock which we can turn into ore — close enough to us so that we can keep an enlarged steel industry busy. The other essentials such as energy, scrap, man power, transportation, are things which we might discuss at length, but from the standpoint of engineering applications it would be more profitable to turn attention to other ingredients — manganese and all the rest of the alloys. Unfortunately most of them originate in foreign countries. The conservation of alloys then becomes a very serious matter. I wonder if Mr. Jominy could give us some ideas as to what we are going to expect in the next few years.

WALTER E. JOMINY (staff engineer, Chrysler Corp., Detroit; president ASM; panel member) — Perhaps I should say I wish I knew! The expectation depends upon how long the emergency period will last, and it seems to me the safe assumption to make is that it is going to last a long time and act accordingly. Alloy shortages look as though they are going to be more serious than in the last war because we use alloys so generously for jet engine propulsion equipment parts. Probably civilian industry will have to do with much less than we did in the 1940's, when we complained about the small amount of alloy in steels for heat treatment. It's going to be smaller, I think. One of the things that's going to help us out is the element boron. We should, as soon as possible, learn about its behavior. A lot is known already. It indicates that a most economical use of alloy in steels is to treat them with boron. That gives them additional hardenability; therefore you can get along with the very minimum of alloy. In making that statement I am assuming that you generally want to quench in oil to avoid distortion, and that the part in question will need something like the hardenability pattern in the steel that you used to have.

THUM — The whole problem of substituting one steel for another immediately brings up the

question of what we can use as a criterion of excellence other than reputation of the maker or the steel's chemical composition.

ELMER GAMMETER (director of laboratories, Globe Steel Tubes Co., Milwaukee; panel member) — It is fairly well recognized that the relation between hardness and strength is a pretty good means of measuring the value of a steel for machine or structural parts. This concept has promoted the development of so-called H-band steels, steels which are specified with definite hardness limits at definite distances from the quenched surface. Steels with specified hardenability bands have become quite popular.

THUM — The harder the steel the higher the strength, but there are other things besides tensile strength required. Some steels are so hard they are quite brittle and fail readily under impact. How about this matter of toughness? How does that come into the hardness picture?

GAMMETER — Of course, there are other properties to be used in any comparison as to just what is expected in the final usage. The steel would have to have sufficient toughness to do the job. Much of that is accomplished by heat treatment to produce the desirable structure. It would have to be completely heat treated to get its maximum potentialities.

THUM — Could you be more specific? You say heat treated at a desirable structure. What is the desirable structure?

ROBBINS — Fully quenched to a very high percentage of martensite and tempered. Insure that you have, in the as-quenched condition, at least a 90% martensitic structure throughout that section; when adequately tempered it will attain the most desirable ratio of hardness and toughness in relation to the mechanical properties that are involved.

Now let me take a few more minutes of these people's time and talk a little bit about this business of substitution of alloys from a philosophical standpoint. It applies even under ordinary conditions. I'll take the operations of a tool manufacturer with which I have been long connected.

When we had field troubles, instead of looking within our own operations — heat treating, for example — we picked up the slack of poor heat treating by putting a richer alloy into the product. Cost of the alloy at that time didn't mean a great deal in relation to the selling price to the customer. We weren't faced with a shortage of alloy, so in place of the 4140 we could buy 4340 with 2% nickel, or we could get the mill metallurgist to cook up an analysis that would do the trick with almost any sloppy heat treatment.

That situation is common, too. There are many parts in all sorts of commodities being made in the United States today using richer alloys than are necessary simply because of the economics of plenty. None of us have been faced with the necessity for devising, on our own, a series of analyses to manufacture the parts that we are making, compositions suitable for best field service conditions, and yet use the *minimum* amount of alloy. When we start a discussion like this, our approach to the problem is, not what is best for the service intended, but what will be equivalent to the steel we have been using. Walter Jominy talked a moment ago about matching the old hardenability pattern. It impresses me that what we ought to be talking about is, "What do we need for the job under field service conditions?"

If every one of us conscientiously approached our specification problem from the standpoint of a system of economics in scarcity, and what we *need* rather than what we *want*, we would be approaching our job in a much more satisfactory manner. I believe that there would then be a much greater amount of alloy available to all of us. I don't believe any of us need to look very far within his own operations to find a job that's overgraded. There is a tremendous amount of alloy that goes down the drain, year in and year out, simply because the metallurgist on the job is using it to mask poor heat treating, or just isn't making the effort to tailor his specifications to the service requirements.

THUM — Hear, hear! This, gentlemen, is the advantage of having a panel discussion which is totally unrehearsed. If we had talked together ahead of this meeting, Fred would have gotten this matter off his chest, and then this afternoon he would have thought: "Well, that's been said once, so why say it again?"

JOMINY — I was very happy to hear it said that you should have 90% martensite as a minimum in the quenched condition. I have been preaching that around the country for quite some time, and it did me good to hear somebody out here in California back me up and carry the ball. One question is: How deep should that 90% martensite be below the surface? At the Chrysler Corp. we have worked

Shallow hardening steels usually distort less —Jominy

to the side that Fred suggests — that is, to the shallow hardening side. We think that shallow hardening steels, when chosen so that you get the proper amount of hardenability at the surface or at about one quarter of the distance from the surface to the center, give excellent performance. I know that millions of parts have been so hardened and have been very successfully used. Parts seem to distort less when you work to that hardenability, so there are auxiliary rewards for using a lower alloy steel if you can possibly do so. If the part is stressed in torsion or in bending, then one quarter of the distance from the surface to the center is all that needs to be 90% martensite.

There are others who think it doesn't have to be that deep. You will find, of course, if you buy steel according to the H-band specifications, that the allowable variation in the hardenability of the steel will be such that if one quarter of the distance from the surface to the center quenches to 90% martensite when the steel is on the minimum side of the hardenability band, it will harden right through to the center when on the maximum side of the hardenability band. But you can aim at something low to begin with, and your criterion is "What is the lowest alloy for the minimum hardenability I can put up with?" If you feel that you can put up with less than you are now using, fine.

THUM — This is a real contribution to the problem of conservation. If we get no further than this and clarify some points which may be in the minds of the audience we will have done a good job this afternoon. Is there anyone in the audience who has some questions?

GENTLEMAN IN AUDIENCE — Mr. Robbins stated that metallurgists have been faulty in their approach to the problem. Many of them are at a decided disadvantage because their firms have no stress analysts. I have seen many instances where parts were designed three or four times heavier than they need be, purely because the men wanted to make sure that they looked all right. Proper techniques of design certainly would conserve more material in the small plants than the larger outfits are wasting.

JOMINY — I think that is frequently true, but there is a continual debate between designer and metallurgist. Early in my experience I addressed myself to the chief engineer of one of the large automotive companies and said: "Now if you will just give me the stresses on this part, I would like to assign a material scientifically to it." He just sat back and laughed and said, "We don't know what they are!" It's only recently that we know very much about what the stresses really are in moving parts — even then the chief engineer likes to have a number of parts made and tried out before he is sure. Usually, it's a long job of cut and try and figure. Education that you speak of is badly needed, but we even have to educate the designer himself.

HENRY A. DOERNER (metallurgist, U. S. Bureau of Mines, Albany, Oregon; auditor) — I would like to return to the topic of alloying elements, their supply — specifically to the problem of manganese and its conservation. I have had some correspondence with Dr. Austin on this matter.

AUSTIN — There is no question that a potential shortage of manganese exists, particularly with the Russians behaving as they have been lately — shipping a little every now and then just as a sort of a teaser, and then shutting if off entirely. The gap is being filled at the moment by imports from India, from Africa and some from Brazil. Ores from Brazil will be increased. We have also a very attractive potential reserve in this country in such things as openhearth slags in our slag dumps. Some of Mr. Doerner's colleagues in the Pittsburgh station of the Bureau of Mines are working on the problem along with many other people.* An associated question is, "What can we do to save manganese in the openhearth process?"

There is no doubt that if the boss were breathing down the melter's neck all day long we could probably save a little manganese. I don't think it would be as much as has been claimed by some people. You also have to recognize the personal element in all these changes or substitutions. If you take a famous oil painter like Winston Churchill and give him water colors, he may not be able to do much with them until he "gets his hand in". If you suddenly demand that the steelmakers of the country start producing the same results with considerably less manganese, you have changed the medium in which they are working. The results will not be what we would like to see. However, if the manganese supply is suddenly cut off, and we are faced with it, I think we

*EDITOR'S NOTE — See, for example, "More Manganese From American Ores and Slags" by E. C. Wright, *Metal Progress*, March 1951, p. 347.

Manganese conservation means more expense in other operations — Chipman

are going to manage, but in the meantime, anything anybody can do to conserve manganese or to find better methods of producing manganese will certainly help.

CHIPMAN — One of my ex-students has been working on the manganese problem in a general way for several years. He told me some time ago that the way to solve this manganese problem is to double the price! What he meant was that if economics forced us to use less manganese, we would use a whole lot less. Within limits that is certainly true. You can balance the cost of manganese against the cost of a lot of other things. If you cut manganese in the ordinary grades of steel you run into higher chipping costs on the slabs and billets because of poor surface quality. Essentially, you then are balancing the manganese against man-hours of labor. Man-hours of labor may be scarcer than manganese at certain times. You can use less manganese in common grades of steel if their sulphur content is lower. You can drive the sulphur content lower in the pig iron by a greater slag-fall in the blast furnace. That runs up the cost of furnace operation and cuts down its production; the pig iron may be more valuable to you than saving a little manganese. This manganese problem comes back just the way our moderator summarized his morning session: The way to solve a shortage is to get more of the stuff to use. That's going to be the answer on the manganese problem.

THUM — I was told something that surprised me the other day by a pretty good steelmaker. He said that a considerable proportion of manganese could be replaced by titanium. Does anyone on the panel have any ideas along that line?

AUSTIN — Yes. Did he say anything about the relative costs of this substitution, with titanium sponge selling at $5 a pound?

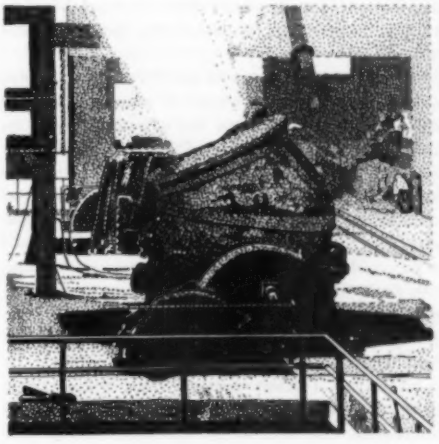
THUM — I think he was talking about ferrotitanium.

AUSTIN — All right, we will talk about ferrotitanium. Even that cost is very much against you, and I don't think the supply is anything like enough. Moreover, I have been told that there isn't enough power in the United States to make enough ferrotitanium to match the manganese output. That is not to say that we cannot substitute *any* titanium for manganese. The possibility that a small amount of titanium can be added along with the manganese is being studied, but it is stretching the point to say that we are going to solve the manganese problem with titanium.

THUM — Perhaps if manganese costs get high enough we might be able to utilize our Chamberlain deposits up in the Dakotas.

CHIPMAN — I think a lot more work needs to be done on those deposits. Maybe since Mr. Doerner raised the question he might elaborate.

DOERNER — The Bureau of Mines has long been concerned with the shortage of manganese from American mines, and we are attacking the problem from quite a number of directions. One was to utilize our domestic low-grade ores and we have studied them from a number of directions. Of course, we realize that you cannot take a low-grade ore and produce a marketable product at a price which is competitive with the



imported high-grade materials. The Bureau of Mines looks at such a problem from a different angle than industry does. Industry is concerned almost entirely with the immediate cost situation, and that is perfectly proper. We are trying to anticipate things that may affect national welfare and look forward to solutions to problems which private industry by its nature is unable or unwilling to undertake. If you can cut down the amount of manganese required in a ton of steel by 50% you are in effect doubling your supply. We are at the present time investigating the relationship between manganese used and the physical properties of the resulting steels. Manganese performs two separate functions. One is to deoxidize and the other is to

Basic cupola will save much manganese in iron castings — MacKenzie

neutralize the effect of sulphur. We believe that deoxidation might be accomplished by other less critical elements. Titanium has been mentioned but there are others, and we are attempting to get quantitative information on the minimum amount of manganese that is required in steels containing variable amounts of sulphur to produce the required physical properties. In any future shortage of manganese that information will be very valuable indeed.

THUM — Thank you, Dr. Doerner. There's no question but that this problem of manganese is exceedingly complicated. Walter Jominy informs me that it also has a distinct bearing on hardenability, so almost any substitution you might make for it would have to be looked at from a number of angles, both technical and economical.

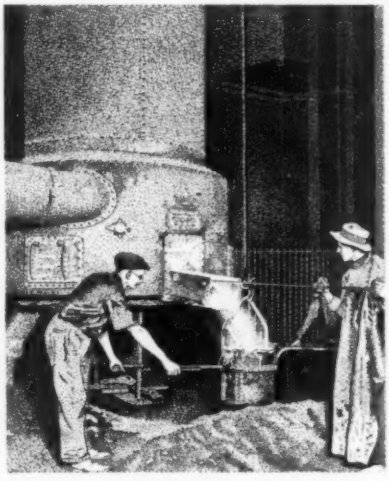
JOMINY — May I add just one thing there which shows how awkward a situation we are really in now. We can do a lot of work on manganese conservation. We can get to use different things at a greater cost. Then all the Russians have to do is to send over a couple of boat loads of manganese ore and the bottom drops out of the whole thing. They can make us pay a fearful price by just teasing us along with little bits of manganese. It is a very awkward situation. It would be better almost if we knew that we would never get any more ore from Russia.

THUM — I have figures here from Earle Smith, chief metallurgist of Republic Steel Corp., concerning the source of manganese. In the last year of which he had records of world trade, the Soviet Union shipped 2,250,000 metric tons of ore out of a total world production of 4,250,000. That's more than half, so you can see that when the Soviet Union pinches its exports down to practically zero it really is making a very serious situation in world trade. In that particular year, the U. S. consumption was about 2,250,000 short tons of ore. At the present time I believe approximately 10% comes from Montana, and the rest from foreign imports.

AUSTIN — We are getting at the moment, I believe, about one third our requirements from India, another third from Africa, and the rest from other miscellaneous sources. Some of you may have seen in the paper within the past few days that the U. S. Steel Co. is going to develop a manganese property in southern Brazil, in a region where there is some very high-grade ore.

THUM — Now perhaps we can proceed and ask some of our experts here what are our other possibilities in alloy saving. Let us start . . . .

JAMES T. MACKENZIE (vice-president, American Cast Iron Pipe Co., Birmingham; auditor) — Might I make a remark or two? In gray cast iron, especially through recent developments in the operation of a basic cupola, there is quite an opportunity for saving in manganese. With sulphur down as low as 0.030% — which is quite readily obtainable even in high steel mixtures, the necessary manganese has dropped down to around 0.4% instead of 0.6 to 0.8%. There have also been some very interesting experiments at the University of Alabama on the substitution of zirconium for manganese. It seems quite successful. The third innovation I would like to mention is the process developed by the Union Carbide and Carbon Corp. of blowing powdered calcium carbide through a refractory tube



into the molten steel bath; we have tried it very successfully on acid electric steels.

THUM — Mr. MacKenzie's production of low-sulphur iron (for so-called nodular malleable) by melting the iron in basic cupola to very low sulphur is a notable achievement. Obviously a byproduct is an iron with correspondingly low manganese. The zirconium idea, I believe, was advanced shortly after World War I, but the cost again comes in here quite emphatically. Walter Jominy mentioned boron steel earlier in

Boron needs well-made steel plus intelligent heat treatment —Digges

this meeting. The American Iron and Steel Institute has recently established certain analyses as tentative standards. Do you know, Tom, what the situation really is here?

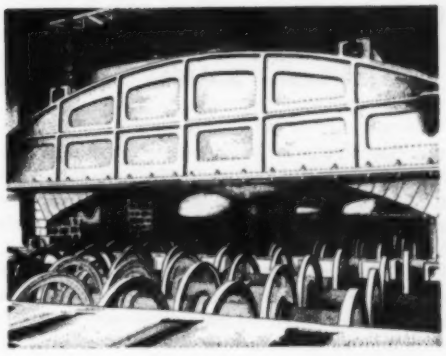
THOMAS G. DIGGES (metallurgist, National Bureau of Standards, Washington; panel member) — It is now a well-established fact that the hardenability of certain types of steels is materially enhanced by the addition of a small amount of boron. As the primary role of an alloying element in the structural engineering steels is to improve hardenability, boron can be used as a partial or complete substitute of the strategic alloying agents now commonly used.

Effectiveness of boron, however, depends not only on the base compositions of the steels but also on the deoxidation practice. That is, a steel can be treated with boron without its hardenability being improved. Published results indicate that unless the boron is in solid solution at the time of quenching, it is ineffective in increasing the hardenability. Although boron is used principally to increase hardenability, some available information indicates that it also improves the notch toughness at room temperature of certain steels when fully hardened and tempered at relatively low temperatures.

The Technical Committee on Alloy Steels of the A.I.S.I. has recently announced two series of lean alloy steels each treated with boron. One series, designated as 80Bxx, contains an average of about 0.30% nickel, 0.12% molybdenum and 0.25% chromium, and is designed to have hardenability equivalent to the 86xx steels of the same carbon content. The other series, designated as 81Bxx, contains an average of 0.30% nickel, 0.12% molybdenum and 0.43% chromium and is designed to have hardenability equivalent to the 41xx series. These new lean multiple alloy steels are designed to make maximum use of the alloys contained in scrap. They are already in the early stages of production.

THUM — I wonder if either Robbins or Jominy would be able to indicate the range of applicability of these boron steels — are there any limitations to their use?

JOMINY — Most American metallurgists believe that all steels, if quenched properly to martensite and tempered to a hardness between 200 and 400 Brinell, have very nearly the same mechanical properties. As far as we know, the



boron treated steels are no exception. They have a reputation for requiring lower tempering temperatures — that is to say, to get the same hardness you don't temper as high — and if you don't get all martensite on the quench they are not as satisfactory as other steels where you do not get an all-martensitic structure. It seems as though the products of slack quenching or high tempering are not as good in behavior. These are things which we are learning pretty fast and that much has already been published.

ROBBINS — Boron steels to us are not substitutions. They are a part of the idea I have already expressed of the desirability of tailoring the steel analysis and its cost to the requirements. I am talking about mechanics' hand tools — not particularly severe service conditions and relatively light sections. Back in 1944 we talked two of the major steel mills into making us an ingot each of a 0.43 to 0.51% carbon, 0.70 to 1.00% manganese steel, treated with boron. Previous to that time and prior to World War II those tools were made out of S.A.E. 4142. During the war we changed to N.E. 9442. Picking ideas out of the air, as you might say, we came up with a minimum hardenability specification of J-45 at $\frac{1}{16}$ in., and felt that this would give us approximately the as-quenched martensitic condition and the tempered structure we desired, to attain the results necessary for field service. Since that time Plomb Tool Co. has used about 40,000 tons of that product at its four plants. Consumption during the end-of-the-war years, when business was awfully good, was high, and it is high again now. We have found out many things in connection with it.

To begin with, Tom Digges has told you that a steel plant can make a boron treated heat and not get the effect of enhanced hardenability.

Boron steels are quite uniform ingot to ingot and heat to heat — Robbins

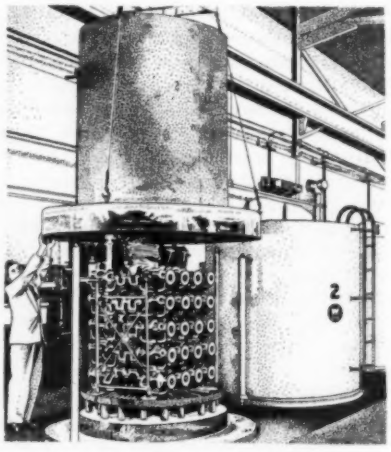
We had a little of that at the start, but babies have to learn to walk too! We have had relatively little difficulty with deficient hardenability as time went on. We have found many interesting things in connection with its fabrication. We do quite a lot of closed die forging, for example. Whereas on the 9442 steel we had been getting about 11,000 pieces per die-sink, with the steel I am talking about, boron treated, we were able to raise that to an average of 26,000. We found, further, that because of the lean alloy and its tendency to temper at lower temperatures, we were able to foster more satisfactory machining in the secondary operations. We know that such savings are considerable from the effect on our direct and indirect costs.

I might add also that at the beginning the steel plants did not add any alloy at all to the melt because the melting scrap contained residuals, particularly chromium and nickel, as much as 0.15% each. Maybe a little molybdenum would be found occasionally, but so long as we were able to maintain the J-45 at $\frac{5}{16}$ in. minimum we didn't much care where the top side of the curve went. When we tailored our heat treating operations to accommodate the absolute minimum, we were able (by adjustment of tempering temperature primarily) to accommodate the different levels of hardenability in the steel that we obtained from the mill.

We have had relatively little difficulty, but I think our sources have had more trouble at the beginning than they were willing to confess — more off-heats at the beginning than now, certainly. I think it is safe to say that the yield is of a relatively high order, and of course that's economically important. Recent changes in the steel extra card for a guaranteed hardenability has caused us to revise our original specification by calling for 0.20 to 0.40% chromium, maintaining the carbon and manganese and the boron treatment at the levels I gave a moment ago. We find now that instead of getting a sharply breaking curve at about $\frac{5}{16}$ in. on the Jominy end-quench test bar, we have leveled the curve out considerably at that point, so that an average over 10 heats might run J-45 at 8/16 or J-50 at $\frac{5}{16}$ in. Boron treated steels without the presence of alloy have a very sharply breaking curve, and if there is no nickel and no chromium and the dependence is entirely upon the boron, carbon and manganese, then that curve will be found to break at just about $\frac{5}{16}$ in. for a 0.43 to 0.51% carbon and 0.70 to 1.00% manganese steel. Naturally, when we added this 0.20 to 0.40% chromium and eliminated the guaranteed hardenability, it straightened out the curve and took out the sharp knee.

We have used, as I said, somewhere around 40,000 tons of the material. We don't consider it a substitution at all. We have complete confidence in it and are extremely grateful to our steel sources for having done the remarkable job of development.

THUM — That seems to be a very intelligent way to tackle the problem. I believe that at about the same time that Robbins' firm got



into this, Caterpillar Tractor Co. also took up boron steel. Can anyone tell us about it?

JOMINY — I have no specific information, but I believe they have continued to use the boron treated steels. Experience pretty much confirms what Fred has been saying, that it has been uniform — and nonuniformity is the thing that seems to worry many people about boron treated steels. There will be no trouble from nonuniformity if the boron content is used merely as one factor which makes an acceptable hardenability test. If the boron has been properly protected from oxidation in the steelmaking process you will find it there if you want to look for it in an exact analysis, but since you want hardenability, an end-quench test is a very intelligent way to verify its presence.

THUM — I believe that hardness tests are performed at the mill; off-heats don't arrive at any Caterpillar plant.

Phosphorus confers useful hardenability — Chipman

ROBBINS — Let me say a little more about uniformity, if I may interrupt. At the beginning we were all concerned with the uniformity. If you get the boron into the ladle how is the first ingot going to compare with the middle and the last one, and how about it from heat to heat? Nobody knew enough to reassure us, and I may say that everybody was rather skeptical. Many people still are. So at the start we set up, with the help of our steel sources, a series of tests whereby they selected a Jominy hardenability sample from the first, middle and last ingot, and the top, middle and bottom cut from each of these ingots. The mill ran a Jominy test on these nine samples, and sent us duplicates and we also ran hardenability tests. We found occasionally, if the heat were not fully deoxidized when the ladle addition was made, that the last ingot would show a little lower hardenability. Very often when the curves were drawn and superimposed upon each other, they were completely contiguous for the different cuts of the first, middle and last ingots. It was a rare occasion when we found a difference of two or three points of hardness at $\frac{5}{16}$ in. within the confines of a heat. We soon got away from that extensive testing, and now take only one sample from each heat. The mill runs one bar and we run another cut immediately adjacent, and we feel quite satisfied.

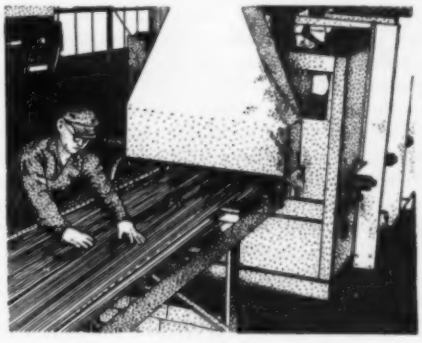
Proof of the pudding is in the eating. I will put the tools we make out of boron steel up against anybody's tools any time, strength for strength, and section for section. To me that's the best evidence.

DIGGES — To obtain some idea of uniformity of boron in commercial steels, reference is made to a heat prepared and tested under the auspices of Army Ordnance during the past war. This was an openhearth heat made by Carnegie-Illinois Steel Corp. that consisted of about 32 ingots, each weighing approximately 8600 lb. The procedure was to make the boron additions with one of seven "intensifiers" in the mold at regular intervals throughout pouring in order to have ingots of three different boron contents treated with a selected intensifier. The hardenability curves obtained from end-quench tests were quite similar for boron-treated specimens prepared from the ingots and for specimens prepared from bars after hot rolling to 1¼-in. rounds. Furthermore, regardless of the composition of the intensifier and the amount of boron retained, the hardenability was markedly improved by each boron addition. The base composition of this heat was 0.43% carbon, 1.6% manganese and it was intended as a substitute for A.I.S.I. 4145. The average hardenability of the boron-treated steels was about equivalent to that of 4145 when comparisons were made on the basis of 95% martensite and slightly inferior on the basis of 50% martensite.

THUM — Evidently boron will be able to conserve a considerable amount of chromium and nickel. There might be some other possibilities. I wonder could Dr. Chipman tell us if there is any chance of picking some other element out of the periodic sequence, such as nitrogen or phosphorus, and making a good alloy with it.

CHIPMAN — You never can tell what somebody is going to pick out of the periodic table because there are so many elements there! You have — probably with design — picked a couple of them that are rather interesting. In making steel we go to a lot of trouble to get phosphorus down to a low level. Sometimes that's costly. Sometimes I think perhaps we may sacrifice something when doing that. Phosphorus as an alloying element is soluble in austenite; it is soluble also in ferrite, and there it has quite a stiffening and strengthening action. Phosphorus even in small quantities also contributes rather considerably to hardenability. I think just from the hardenability standpoint alone some further consideration and study of phosphorus would be justified.

The other element you mention is nitrogen. Now, nitrogen isn't something which you throw into the ladle in steelmaking; it is something that is always present. There is more of it in bessemer steel than in openhearth steel. It is an element which in general is not desirable because it leads to brittleness of one kind or

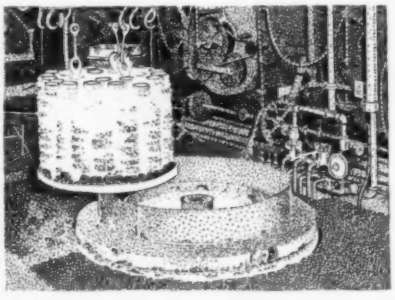


Case hardening — especially carbonitriding — will conserve alloy

another. Consequently, ways and means have been devised of making bessemer steel which is lower in nitrogen, and that is quite a useful accomplishment. Nitrogen, though, is an alloy which does stabilize austenite, it does contribute to hardenability, and therefore it should not be overlooked.

Steel treaters have not been backward in using its virtues. There are two methods of putting nitrogen into the surface of steel, one of which, I think, may be very usefully considered from the standpoint of nitrogen as an alloying element for the conservation of other alloys. Steels for nitriding are pretty highly alloyed, so you are not saving very much alloy when you go to the nitriding process for surface hardening. However, the more prevalent process of carbonitriding is not nitriding at all — it's carburizing with ammonia present in the carburizing atmosphere.

Carbonitriding can be done at a couple of hundred degrees lower than carburizing. This is useful because it minimizes distortion or sagging. A more important feature is that a plain carbon steel which is carbonitrided can be oil quenched for hardness, whereas the same steel carburized must be more drastically quenched. Oil quenching is highly desirable from the standpoint of lower distortion. This frequently means that a plain carbon steel, carbonitrided, can in certain instances replace alloy steel, carburized. I think here is the way in which nitrogen can play its part as an alloying element in steel.



THUM — John Chipman has brought up two alternatives: first, the use of phosphorus as an alloying element; second, the use of nitrogen (preferably with carbon) as a surface hardener. Let me separate these two and ask Dr. Austin if he could give us any information he may have on the possibility that phosphorus might be utilized in tonnage steel production as a hardener.

AUSTIN — I have no information on the use of phosphorus as a hardener in tonnage steel.

THUM — The answer, then, is that it has not yet been given serious attention — at least as far as your laboratories are concerned.

AUSTIN — Not as far as we are concerned.

JOMINY — I would like to point out that you have to be rather careful about the amount of phosphorus if you are interested in impact resistance at low temperature. In our experience the transition temperature — where you change from brittle to ductile fracture — seems to be raised by the presence of much phosphorus. The other difficulty we have had with steels that ran high in phosphorus has been a tendency for quench cracking, but we do agree with John that it does add to hardenability and I think that in certain size sections it probably should be considered.

THUM — I was going to ask you to continue with the proper applications of case hardening as methods for conserving alloy.

GAMMETER — I think what has already been said has been very well put. It's absolutely our experience in production that the increase in hardenability that is obtained from the nitrogen content of a carbonitrided case is considerable; it does enable you, in many instances depending upon the section size, to quench in oil without soft spots where you would otherwise have to quench in water. It is a process that is being used more and more, and it has a number of advantages. In some instances, if your section is thin enough, you can carbonitride and not quench at all and come out with a hard surface.

ROBBINS — John, you said a few minutes ago (we are talking about carbonitriding) that you could sometimes make a substitution for carburized steel such as 8620 for a completely hardened part. What about the core properties?

CHIPMAN — The core properties are, of course, those of the original steel. The nitrogen penetration is very slight and the core properties are just what you have from the steel itself. It could then be put through various treatments.

ROBBINS — In an application where you must have a strong core to back up the case, such a substitution for a stronger or deeper hardening alloy wouldn't be satisfactory.

CHIPMAN — You are correct in that.

ROBBINS — Where abrasive wear is an

Analyze parts which work in torsion or bending —Jominy

important factor that the carbonitriding process could be used?

CHIPMAN — That is the opportunity to use it.

ROBBINS — That's important. Tailoring it again to the field service requirement. That's the only approach a metallurgist should ever make to these things. We have to bring it down to "What are we going to do with it, and how is it going to be used when we get it made?"

THUM — I had somewhat the same thought. It seems to me that if you want a hard surface the way to get a hard surface is to put some nitrogen there. I asked Walter Jominy if he could elaborate that thought in the manufacture of automobile camshafts. He said Chrysler is making camshafts out of cast iron. This seems to be an ideal example of alloy conservation.

JOMINY — The cast iron camshaft gives you superior wear resistance when properly hardened due to, I think, the presence of graphite. I was going to say that there are many uses for steel parts which merely require a surface hardness. In such places we are using carbonitriding to advantage in saving of alloy steel. Even where a considerable depth of hardness is required you can carburize rather deeply, and strength penetrates pretty far. In such cases there will likely be a discussion between designer and metallurgist as to how deep that hardness *has* to penetrate, and what core properties are really required. When you stop to think that parts that are loaded in torsion or in bending are stressed highest at the surface and the stresses reduce to zero as you approach the center, in many such cases you can use less alloy in the part and harden the surface layers properly by the carbonitriding process.

GENTLEMAN FROM AUDIENCE — One thing that is extremely important connected with high surface hardness is the fact that after proper heat treatment you also get a good deal of compressive stresses locked into the case carburized surface. Oftentimes the combination of prestress and hardness will eliminate the need of an extra strong core when you have a part serving in torsion or bending.

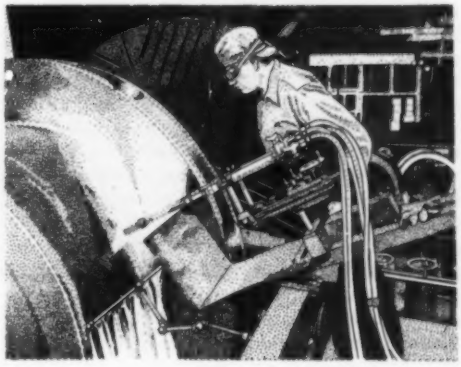
THUM — Let's have more comment from the floor. We have been talking along, thinking that we know what's best for the listeners out in front.

RALPH L. WILSON (director of metallurgy, Timken Steel & Tube Div., Canton, Ohio; auditor) — I would like to turn this back to a discussion about dry cyaniding (or carbonitriding, as some call it) without complicating it with core properties. Boron carburizing steels are now being offered as substitutes for the old standard steels, instead of compositions based on equivalent core hardenability. I just want to make the point that the case hardenability, being in the high-carbon region, does not get the benefit of any increase due to boron. Maybe the combination of dry cyaniding and boron steels will go together. We know, too, that if boron steels are carburized at too high a temperature you may get into trouble; if you can take advantage of a lower carbonitriding temperature, that would help also.

ROBBINS — Ralph, you just said that you know that higher temperatures get the boron steels into trouble. Prove it.

WILSON — It doesn't happen to be my own experience, Fred, but it is pretty well documented. The particular example I have in mind was a carbon-manganese steel, boron treated — a ferroboron openhearth product. The original experience was that if you carburized at 1700° F. and direct quenched you didn't get the expected hardness. It was later discovered that if you would, say, let the temperature fall from 1700° F. (which is the conventional gas carburizing temperature) down to 1550° F. (which is OK for carbonitriding) and then quench, you get the expected hardness.

ROBBINS — Well, I don't see how you can precisely lay that at the feet of boron. The reason that I come back to the subject is that Tom Digges and I got into a fuss by mail on that subject three or four years ago. We do a lot of closed die forging in drop hammers. Hammermen, lots of them, would rather *cast* on those forging dies than to forge, and the problem



of overheating concerns me quite a bit. I would like to know if they are doing anything else to the steel besides making the grains as big as a marble and burning it every once in a while. What are they doing to the hardenability? As nearly as we have been able to determine, the boron steels are a little more fool-proof than many of the richer alloys; they don't seem to be damaged as much by that kind of mistreating in forging. I don't have any information at all on carburizing of these materials because we use no carburizing steels.

THUM — What part of that statement, Digges, do you disagree with?

DIGGES — I have disagreed with Fred in that it has been my experience that the action of boron on hardenability can be adversely affected during the course of forging or other thermal treatment. I refer especially to the results of hardenability tests made at the National Bureau of Standards on high-purity iron-carbon-boron alloys as cast and as forged and homogenized. The cast specimen had the expected improvement in hardenability due to boron, whereas the same compositions after forging and homogenizing did not show the enhancement. It is not claimed that the forging treatment used was representative of commercial practice. I believe another point where there is possibly some disagreement is the effect of boron on austenite grain coarsening temperatures. I have found that steels deoxidized with aluminum and treated with ferroboron often coarsen at lower temperatures than similar steels without boron.

ROBBINS — I guess that I can agree with that, too. I don't want to be jockeyed into the position of defending boron necessarily. I would agree to be jockeyed into defending the finished parts that we make out of the boron steels. I have been rather inclined to believe that a part of the recorded difficulties is tied back to the same trouble that we all had when we attempted to use the N.E.8600, 8700 and 9400 series. They were new steels. For one thing, we didn't know how to anneal them properly for best machining. For some years after they had been made available the users ran into many difficulties. I would predict that we will have lots of trouble in making substitutions with the new boron steels recently adopted by the American Iron and Steel Institute, but I would like to recommend a little bit of patience in handling them. I think, Tom, that both you and I believe that the kind of mistreatment that has been mentioned would be very bad, no matter what sort of steel you were using.

DIGGES — There is another fact that is important to consider in the successful treatment of steels with boron. If a steel contains relatively high soluble nitrogen, it has been found that the boron is relatively ineffective in improving hardenability. In such steels, apparently, the nitrogen reacts with some or all of the boron. However, it is possible to retain the boron effect in high nitrogen steels by the use of strong nitride-forming elements, such as titanium or zirconium, to fix the nitrogen and thus decrease the amount of soluble nitrogen for reacting with the boron. The nitrogen content is usually sufficiently low in steels made in the openhearth or other commercial processes so that the desired improvement is obtained in deoxidized heats treated with ferroboron.

GENTLEMAN FROM AUDIENCE — In working with these boron treated steels we know that there are instances where reprocessing or reheat treating is necessary. What is the best reconditioning or remedial treatment to be used? Full annealing, normalizing or both?

ROBBINS — The ideal treatment would be normalizing and then annealing. You can't always afford that. When you can't, you can anneal alone in order to promote further secondary machining operations or other processing you are going to do. Ideally, though, any heat treated object ought to be normalized before you start all over. It then gets the best break — but, of course, metallurgists are frequently called upon to compromise their ideals with their necessities.

GENTLEMAN FROM AUDIENCE — When you spoke of the carbonitriding process were you referring to such a process as Chapmanizing?

CHIPMAN — No. We were referring to the use of a carburizing gas plus a little bit of ammonia, or a straight hydrocarbon such as methane or propane with a large amount of ammonia. In the molten salt bath the ammonia is bubbled up through it and disassociates into nitrogen and hydrogen. Some of this nitrogen is absorbed by the hot steel surface.

GENTLEMAN FROM AUDIENCE — I would like to mention that a little nitrogen — on the order of 0.008% — has found a useful purpose in tinplate. It increases the work hardenability of the steel. That is to say, the necessary stiffness for a can-end can be had with one light pass in the cold mill, rather than two passes on a

heavier pass. It gives a stiffer plate with a small reduction.

THUM — Any other questions now?

WILSON — I would just like to return to phosphorus, its use in steels that are not heat treated. There have been many very useful steels produced that are called low-alloy structural steels, or low-alloy, high-tensile steels. They are supplied in the form of plates and shapes. A few years ago there was a rash of offerings — two of them, as I recall it, utilized phosphorus as a strengthening medium rather than carbon. The phosphorus might be about 0.15% in a 0.10% carbon steel. These two (and some others as well) used considerable copper. The Inland Steel Co.'s offering contained ordinary manganese — about 0.60%, and about 0.50% nickel as well. It was classed as a low-alloy, high-tensile material, and yet by A.I.S.I. definitions didn't reach the alloy limits for alloy steel.

ROBBINS — On that last, there is a lot of trouble with nomenclature, isn't there? Is there any definitive place where alloy steel starts and carbon stops?

WILSON — Yes there is, Fred. You could, for example, have up to 0.60% copper in carbon steel and it could still be carbon steel.

THUM — That's purely a definition, though.

WILSON — Yes. It's a commercial definition, but an important one, not only to American trade but to foreign imports.

ROBBINS — I am pessimistic enough to think that when we find a good place to use a 0.60% copper steel, somebody will begin to want to charge us an extra for it, probably on the basis that it is an alloy steel.

WILSON — You will be surprised. The 0.60% copper limit is tolerable copper, and if you buy carbon steel scrap you are apt to get that much tramp copper in the scrap and we are not supposed to complain about it.

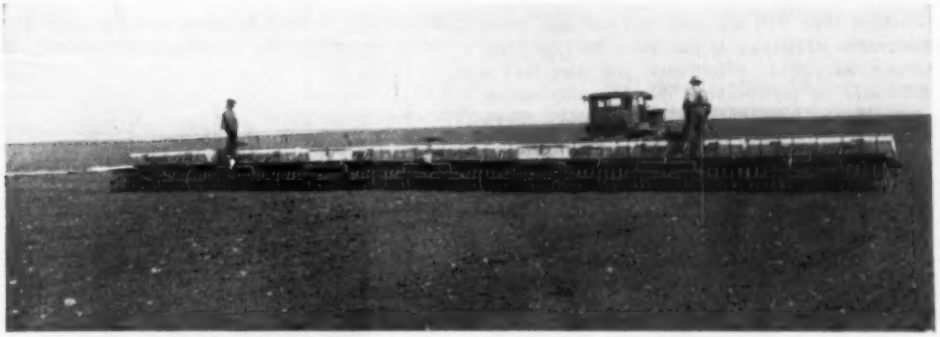
So when we have to make steels like the 8000 and the 8100 series, and you take a look at the bottom limits on the alloying elements, you are at the level classed as carbon steel. You make the steel as an alloy steel, and when your customer has some left over as chips, that goes to market as carbon steel.

ROBBINS — You see, gentlemen, he does agree with me after all. He didn't admit it until the last sentence.

THUM — Digges, did you have a comment you want to make?

DIGGES — Ralph Wilson has referred to the use of phosphorus in low-alloy-high-strength-structural steels. It may be of interest to point out that strategic elements are conserved by the use of scrap in preparing some of the steels comprising this family designated for use at yields of about 50,000 to 55,000 psi. Their superiority in strength, with ample ductility, is provided by the use of alloying elements such as phosphorus, copper, nickel, molybdenum and others. Copper, nickel and molybdenum are recoverable from scrap and this is a source that is used as a basis to build up these elements to the desired level.

THUM — I want to put in a philosophical remark if Fred will let me poach on his reserves. In my experience there have been a few important milestones. Metallurgical practice and science leaped ahead after the perfection of the indentation hardness test. Probably all of the gray heads around here can remember when we went to technical sessions and listened to discussions of the Brinell test, just being imported from abroad. That was a most important measuring



On Montana Prairies It Costs a Penny an Acre With a Caterpillar Diesel Tractor and John Deere Van Brunt Seeders

Steels of equivalent hardenability are equivalent in other properties — Jominy

tool. Another which was responsible for a tremendous advance in application metallurgy of steel was the pinning down of the concept of hardenability. That has been recent enough so there may still be a good deal of uncertainty on the part of people who have not used it at all or only used it partly. Presumably they might well welcome an assurance from one or two of the people here on the panel who have used it a great deal. They would welcome an assurance that equivalence in hardenability bands really means ability to replace one steel with the other. Is it true, Mr. Jominy, that steel A which has a certain hardenability band is equivalent in its use and mechanical properties to steel B which has the same hardenability band, even though it may be far distant from it in chemical composition?

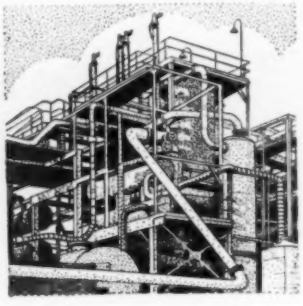
JOMINY — From the standpoint of mechanical properties it is, if you are interested in hardnesses between 200 and 400 Brinell, provided you will harden each of the steels to give you a microstructure of at least 90% martensite. After drawing back to equivalent hardness, then the properties are usually quite comparable. There are some small differences, but they are usually insignificant. The British don't quite agree with that; that's why I previously said the American metallurgists mostly agree. The British seem to feel that there is a difference in every steel, mainly in impact resistance and ductility, but over here those differences seem to be very slight as far as they affect our type of commercial usage. We are concerned usually with steels behaving properly within some mechanism — where they will not fail, we will say, from endurance stressing. If you use a steel up completely, as you do a toolsteel, you may find a difference in performance due to composition, although the hardenability is the same. Even in toolsteels we have found that a hardenability test is a very useful tool. Certainly in our shop the concept of hardenability for choosing steels for tool applications has been one that's been most useful in increasing the life we got out of the tool and in decreasing its cost. This is used elsewhere; it is now common to find a hardenability test in toolsteel specifications.

THUM — I take it, therefore, that if we stay away from extremes in hardness and do an intelligent heat treating job we can substitute a low-alloy steel for a higher-alloy steel if their hardenability bands are equivalent.

S. L. HOYT (technical adviser, Battelle Memorial Institute, Columbus, Ohio; auditor) — It seems to me that Walter's last statement needs a bit of modification. I recall a statement that he himself published a few years ago in which he gives the transition temperatures of four different steels all hardened fully and tempered back to the same hardness. He shows that those that contain nickel had a lower transition temperature than those which had no nickel at all. That seems very important in certain applications today, either in the production of liquid oxygen, in the chemical industry, or even in aircraft where the temperatures met at high altitudes may be as low as 50 below zero.

JOMINY — I am glad to hear Dr. Hoyt get up and express himself. He is an expert on low-temperature problems. There are undoubtedly certain specific differences that exist for special applications. In my experience in automotive construction, however, if a steel is heat treated to martensite, and if it is properly heat treated (that is to say, if it is quenched from the tempering temperature when it gets into that zone known as temper embrittlement) you usually have a transition lower than 40° below zero anyway. I studied some of the 1340 steels cited in the publication mentioned by Sam Hoyt just now. I got a transition from tough to brittle fracture above room temperature by abusing the steel. From identically the same steel, by proper heat treatment, I got a transition temperature of 40° below zero. I do think you can get very low transition temperatures in special compositions. As was mentioned here a moment ago, the effect of phosphorus, which if not counterbalanced, seems to raise that transition temperature.

THUM — Gentlemen, now that it is 4 p.m., I think we had better consider the meeting adjourned. I want to thank you for your flattering attention. The meeting is adjourned.



Advertisement

ELECTROMET Data Sheet

A Digest of the Production, Properties, and Uses of Steels and Other Metals

Published by Electro Metallurgical Company, a Division of Union Carbide and Carbon Corporation, 30 East 42nd Street, New York 17, N. Y. • In Canada: Electro Metallurgical Company of Canada, Limited, Welland, Ontario

How VANADIUM improves engineering steels and helps conserve critical alloys

In these critical times when many alloying materials are scarce, you may be able to use vanadium to good advantage. Steels alloyed with vanadium meet most of the mechanical specifications for low-alloy engineering and structural steels. In fact, vanadium can often be used in engineering steels to replace at least part, if not all, of certain alloys now in critical supply.

The metallurgy of vanadium is well known. Small additions of vanadium—0.10 to 0.30 per cent—can be used effectively to give steel extra strength, toughness, and resistance to fatigue and wear. It improves engineering steels by increasing their yield strength without sacrificing ductility. The uniformly fine grain size of vanadium-bearing steels makes them tough and resistant to abrasion, fatigue, and impact.

Better Mechanical Properties

In the following table are typical analyses for carbon-vanadium and chromium-vanadium steels that are suitable for most applications where low-alloy, high-strength steels are required. The carbon-vanadium steel is compared with plain-carbon steel; and the chromium-vanadium steel, with chromium-molybdenum steel. Note the excellent properties of the vanadium-bearing steels.

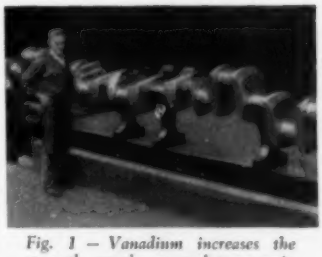


Fig. 1 — Vanadium increases the strength, toughness, and wear resistance of engineering steels for many machine parts, such as this large crankshaft.

Improves Cast Iron

A small addition of vanadium, usually from 0.10 to 0.25 per cent, refines the grain of cast iron, and materially increases its strength and hardness. Moreover, vanadium may be used in cast iron to replace at least part, if not all, of certain alloys that are now in short supply.

Vanadium in Rimmed Steel

An addition of approximately 1 lb. of vanadium per ton of steel produces non-aging characteristics in a rimmed steel. These non-aging properties, together with improved deep-drawing characteristics and the good surface inherent in rimmed steels, make these steels of particular interest at the present time.

Grades of Ferrovanadium

ELECTROMET produces ferrovanadium containing 50 to 55 per cent vanadium for the production of vanadium-bearing steels and irons. The alloy is produced in three grades with maximum 0.20, 0.50, or 3.00 per cent carbon and maximum 1.50, 2.00, and 8.00 per cent silicon, respectively. Each grade is specially adapted to fill the different requirements of iron- and steel-making.

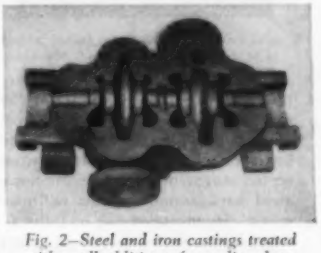


Fig. 2—Steel and iron castings treated with small additions of vanadium have high ductility and greater toughness and impact resistance.

Write for a copy of the booklet, "ELECTROMET Ferro-Alloys and Metals," which gives helpful information about the use of ferrovanadium and other alloying metals that ELECTROMET supplies. The booklet may be obtained from any ELECTROMET office: in Birmingham, Chicago, Cleveland, Detroit, Los Angeles, New York, Pittsburgh, or San Francisco. In Canada: Welland, Ontario.

Properties of Vanadium Steels Compared With Other Engineering Steels

Typical Analysis, %	Carbon Steel	Carbon-Vanadium Steel	Chromium-Molybdenum Steel	Chromium-Vanadium Steel
Vanadium	—	0.16	—	0.16
Carbon	0.50	0.49	0.50	0.50
Manganese	0.71	0.77	0.80	0.79
Silicon	0.19	0.15	0.30	0.31
Chromium	—	—	0.95	0.98
Molybdenum	—	—	0.20	—
Annealed and Furnace-Cooled				
Tensile Strength, psi	90,600	100,000	100,000	99,500
Yield Point, psi	48,900	66,000	50,000	64,100
Elongation in 2 in., %	23.3	25.0	23.0	28.4
Reduction of Area, %	37.8	49.1	45.0	59.0
Izod Impact, ft.-lb.	13.5	26.0	17.0	44.0
Quenched and Tempered				
Tensile Strength, psi	134,900	134,500	232,000	232,800
Yield Point, psi	110,800	128,000	214,500	224,200
Elongation in 2 in., %	18.3	18.3	10.0	10.4
Reduction of Area, %	54.1	56.6	39.0	43.1
Izod Impact, ft.-lb.	54.0	65.0	12.0	12.0

The term "Electromet" is a registered trademark of Union Carbide and Carbon Corporation.

Personal Mention

John Parina, Jr.

JOHN PARINA, JR., has been appointed associate editor of *Metal Progress*, the position formerly occupied by TAYLOR LYMAN (who has been transferred to other duties on the magazine). Mr. Parina has a good background for this editorial work. He attended the metallurgical engineering courses at Fenn College in Cleveland. He started working for the American Steel and Wire Co. in 1937, first in the steel plant, then in the chemical and metallurgical laboratories. In 1945 he joined Penton Publishing Co., becoming associate editor of *Steel* in 1946. He joins *Metal Progress* after three years in advertising and publicity work for the well-known Cleveland firms of Warner & Swasey, and Baker-Raulang Co.

We believe that Mr. Parina will be able to assist the principal editor, ERNEST E. THUM, in many ways in his efforts to continue *Metal Progress* as the outstanding magazine of metals engineering.

WILLIAM H. EISENMAN
Secretary
American Society for Metals

William F. Nash

WILLIAM F. NASH ⊖ has recently been promoted to plant superintendent of C. F. Braun & Co., Alhambra, Calif. Dr. Nash joined the company in 1947 as staff consultant in the field of metallurgy. He took a large part in planning and setting up the metallurgical research laboratories in the plant's new million-dollar research center. In his present capacity as superintendent, Dr. Nash will supervise all manufacturing operations of Braun's factory. He was graduated from the California Institute of Technology in 1942 with a Ph.D. degree in mechanical engineering, and for the following three years he taught classes in metallurgy there. In 1945 he became head of the metallurgy section for the Naval Ordnance Test Station at Pasadena, Calif. Dr. Nash was program chairman in 1949 for the American Society for Metals' Western Metal Congress in Los Angeles, and he is the choice of the nominating committee for chairman of the Los Angeles chapter of the Society for 1951 and 1952.

John Garland

JOHN GARLAND ⊖, who until his recent retirement had been in control of the heat treatment of tool-steels and materials for tools at Ford Motor Co. Ltd., England, for almost 20 years, is the author of many articles on heat treatment and design of tools. He was elected a Fellow of the Institution of Metallurgists in 1947 as a result of his many contributions to the advancement of metallurgy in Great Britain. Mr. Garland received his metallurgical training with Barr & Stroud Ltd., Glasgow, Scotland, making scientific instruments, and his technical training at the Royal Technical College, Glasgow. From 1920 to 1930 he worked as a specialist in the heat treatment of metals and as co-developer of the training program for mechanical engineering apprentices at a British ordnance factory in India. He devised a practical inspection test which enabled Ford Motor Co. of England to find imperfectly heat treated tools without resort to costly and time-consuming laboratory examinations. He described this test in the article "The Hardness Testing and Heat Treatment of High Speed Steel" published in *Machinery* (England) in 1933. The test today is considered standard by the British Admiralty.

Joseph G. Christ ⊖ has taken a position as metallurgist in charge of the Pittsburgh branch of the Ferrotherm Co.

Gordon H. Moline ⊖ has been with Kramer Machine & Engineering Products Co., Leavenworth, Kan., as a staff engineer, since leaving Joseph E. Seagrams & Sons, Inc., last April.

BALL bearings are necessarily made to close tolerances which apply not only to the balls and races but also to the retainers which must have exact dimensions and shapes. This matter of retainer quality has been given careful study by the Stephens-Adamson Mfg. Co., Aurora, Illinois, maker of the well-known SealMaster Industrial ball bearing units. The company collaborated closely with the Revere Technical Advisory Service in working out the specifications and forming procedures for its brass retaining rings. As a part of this joint activity, Revere made a full survey of Stephens-Adamson requirements, with the object of standardizing and simplifying specifications for the benefit of both the engineering and the purchasing departments. The success of this work is indicated by this statement from the Superintendent of SealMaster bearing production: "First and foremost, I am pleased with the uniformity of gauge and temper of the Revere brass we have been receiving. This uniformity makes it possible to produce ball retainers of very close tolerance, with a minimum of rejections and at comparatively low unit cost. Furthermore, I have appreciated the dependable delivery service and the cooperation of the Revere organization."

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Personals

Milton Garvin ⊖, formerly chief metallurgist and manager of the Flamatic Division of the Cincinnati Milling Machine Co., was recently appointed director of research of the Schaible Co., Cincinnati. Mr. Garvin is the author of a number of technical papers on selective surface hardening and is frequently a speaker for American Society for Metals chapters around the country.

Frank J. Altman ⊖ has resigned his position as general fleet superintendent for Omar, Inc., Omaha, Neb., and returned to his former position at the A. O. Smith Corp., Milwaukee, as a research metallurgist in the airframe division.

Robert W. Manuel ⊖, who resigned from Phillips Petroleum Co. to accept a position with the H. K. Ferguson Co., Cleveland, is presently on loan to the Procter & Gamble Co., Cincinnati, where he is assigned to the staff of the engineering division.

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MARVEL is also the only manufacturer of both metal sawing machines and metal sawing blades. Because the efficiencies of both the machine and the blades are interdependent, each upon the capability of the other, expert knowledge covering both saws and saw blades is essential to the proper appraisal of any specific sawing situation. Correct balance of cutting speed and blade life, feed pressure and blade tension are all potent factors in over-all performance. Here again it is the MARVEL Field Engineer who is qualified to provide the comprehensive answer to your question. His job is to help you saw metal most efficiently — his services are available upon request — gratis.

WRITE FOR CATALOG 49

ARMSTRONG-BLUM MFG. CO.
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Robert C. Hammond ⊖ has been employed in the metallurgical division of Aluminum Co. of America's Lafayette, Ind., works.

M. S. Allshouse, Jr., ⊖, has been recalled to active duty by the Navy and has been serving in the capacity of engineering officer aboard the U. S. S. Vermilion (AKA-107).

Robert Y. Scapple ⊖ is now a metallurgist with the Westinghouse Electric Corp., Sunnyvale, Calif.

Aaron Shankman ⊖, recently graduated from the Illinois Institute of Technology, has been employed by the H. Kramer & Co., Chicago, as a foreman in the foundry.

Charles H. Fuchsman ⊖, formerly research chemist at the potash division, International Minerals & Chemical Corp., Carlsbad, N. M., is now a chemical engineer in the research and development department of the Southern Alkali Corp., Corpus Christi, Tex.

John C. Hamaker, Jr., ⊖, who completed work on his Ph.D. in metallurgy at the University of Michigan last June, has accepted a position as plant metallurgist for the General Iron Works Co., Englewood, Colo.

Earl E. Swansen ⊖, formerly research metallurgist at the Chain Belt Co., Milwaukee, has recently become superintendent of heat treating for the company's Baldwin-Duckworth Chain Division, Springfield, Mass.

Robert H. Erskine ⊖ has been employed as a sales engineer for the steel products and specialties department of the Peter Vredenburgh Co., Springfield, Ill., since his graduation from the Missouri School of Mines.

Ernest L. Waterhouse ⊖ has been employed as blast furnace relief foreman trainee by the United States Steel Co.'s Gary, Ind., works.

Virgil J. Knierim ⊖, who graduated from the Michigan College of Mining and Technology in March, has accepted a position as junior metallurgist with the Aluminum Co. of America, Casting Division, Cleveland.

John M. Hopkins ⊖ resigned from the Scaife Co., Pittsburgh, to assume the position as president of the Butalite Corp., Pittsburgh, a new corporation formed to manufacture compressed gas ignition products.

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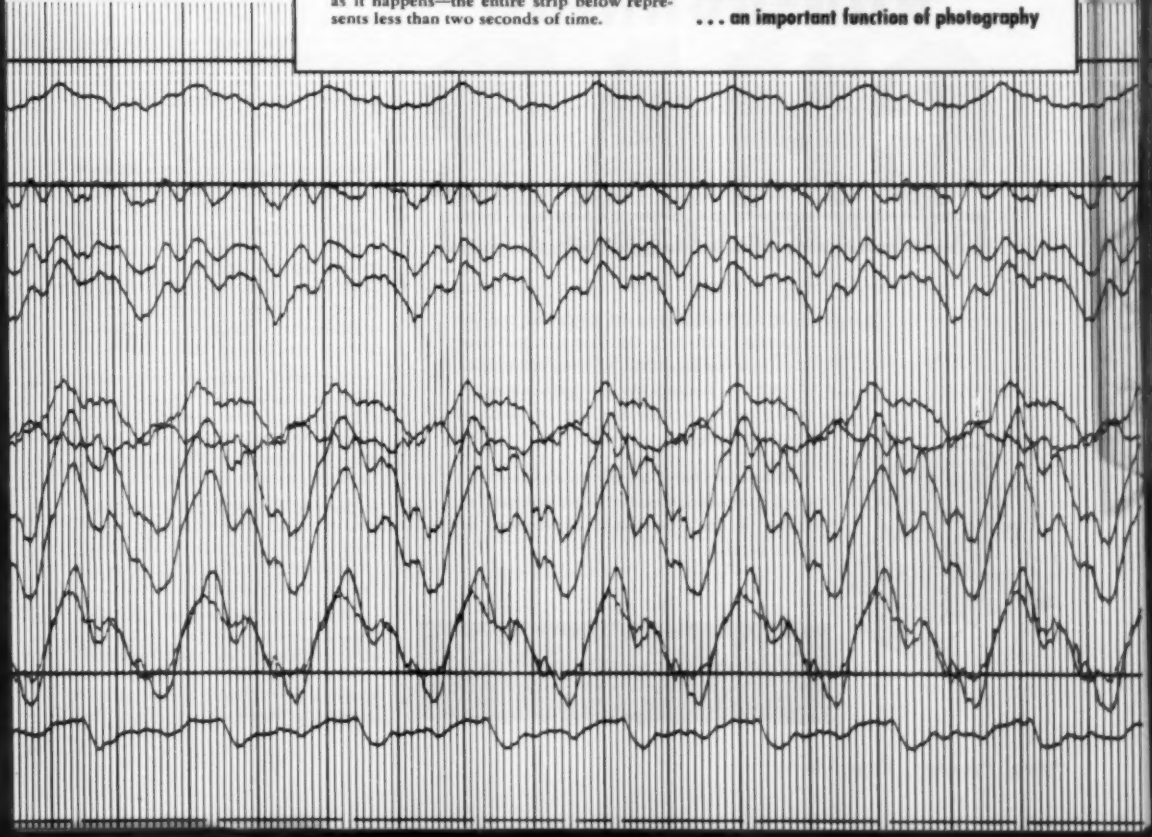


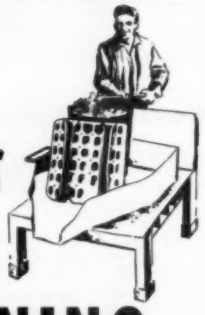
Personals

Alexander Gabay has been appointed assistant to the president of the Wooldridge Mfg. Co., Sunnyvale, Calif.

Donald A. Campbell, formerly manager of Bryant Industrial Division of Affiliated Gas Equipment, Inc., has become associated with the Eclipse Fuel Engineering Co., Rockford, Ill., as vice-president in charge of engineering and research.

E. L. Spanagel has been promoted to the position of assistant manager of the commercial and industrial sales department of the Rochester Gas and Electric Corp. Mr. Spanagel held the office of national treasurer of the American Society for Metals from 1947 to 1949 and prior to that time held office in the Rochester Chapter for 11 years.

M. G. Fontana has recently been elected vice-president of the National Association of Corrosion Engineers.



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Paul M. Winslow has been appointed resident chief metallurgist for the Des Moines, Iowa, plant of Solar Aircraft Co.

Dennis J. Carney has recently been appointed chief development metallurgist at the United States Steel Co., South Works, South Chicago, Ill.

Tracy M. Kegley, Jr., has been appointed to the staff of the Metallurgical Division of the Oak Ridge National Laboratory, Oak Ridge, Tenn.

Fred M. Gillies, executive vice-president of the Acme Steel Co., Chicago, has been elected to the board of directors of the company.

Floyd W. Crouch and **Jaye S. Gamble** have been appointed chief metallurgist and assistant chief metallurgist, respectively, at National Works of United States Steel's National Tube Co., Pittsburgh. **Arthur W. Thornton** has been appointed division superintendent, pipe production, finishing and shipping, and **William B. Kennedy** division superintendent in charge of blast furnaces, open hearth furnaces, Bessemer converters, and rolling mills.

Robert A. Miller, formerly with Battelle Memorial Institute, Columbus, Ohio, has accepted a position with the chemical department of American Brake Shoe Co., Mahwah, N. J.

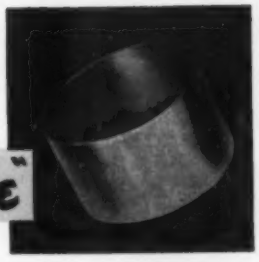
George L. Durfee, a senior metallurgy student at the Michigan College of Mining and Technology, recently was selected as one of eight students in the country to receive a Tau Beta Pi graduate fellowship for 1951 to 1952. He will begin work on a Ph.D. degree in metallurgical engineering at Massachusetts Institute of Technology, Cambridge, Mass., this fall.

Herbert T. Anderson has been employed as junior engineer with the Kaiser-Frazer Corp., Detroit Engine Div., since his graduation from the Michigan College of Mining and Technology in March.

Donald R. Scheid has accepted a position as student engineer with the Alloy, W. Va., plant of the Electro Metallurgical Co., a division of Union Carbide and Carbon Corp.

Harold P. Haberstroh, Jr., has been employed as a metallurgical engineer by the Moraine Products Div. of General Motors Corp., Dayton, Ohio, since graduating from Purdue University.

This one is ordinary drawing brass



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Personals

S. W. Madsen has been appointed sales engineer in charge of special alloys and welding rod coating ingredients for Metallurg, Inc., New York.

Melvin E. Molitor, formerly a trainee at Grede Foundries, Inc., Milwaukee, is now assistant metallurgist in foundry research for the Armour Research Foundation, Chicago.

James R. Bierly has been employed as a metallurgist by the Mansfield Brass & Aluminum Corp., Mansfield, Ohio, since his graduation from Michigan College of Mining and Technology.

Charles B. Cobun, formerly service metallurgist of the Chicago district, United States Steel Co., is now product representative in the alloy sales department, Pittsburgh office. Mr. Cobun has been with Carnegie-Illinois and United States Steel for over 21 years.

Stanley L. Channon, who received his Ph.D. in metallurgy from the University of Illinois in February, has joined E. I. du Pont de Nemours & Co., Inc., Newport, Del., as a research metallurgist.

Walter E. Conrad, Jr., is now employed as an engineer with the National Aniline Div., Buffalo, N. Y., of the Allied Chemical & Dye Corp.

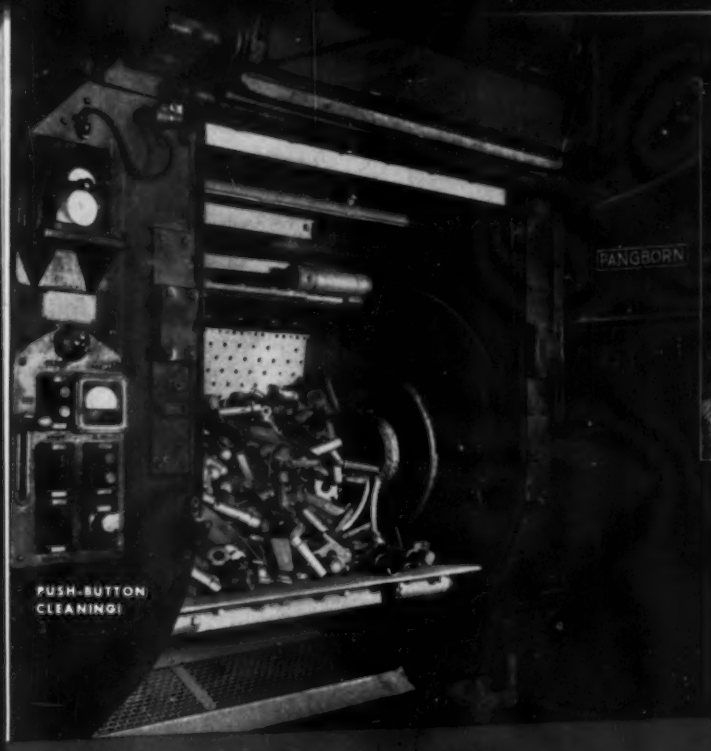
John M. St. John is with the college graduate training program at the Caterpillar Tractor Co., Peoria, Ill., as a trainee.

Frank C. Perkins has been employed as a junior engineer at Sylvania Electric Products Inc., Bayside, N. Y.

L. G. Mustill has recently assumed duties as mechanical maintenance supervisor for the Shawinigan Falls, Quebec, plants of the Aluminum Co. of Canada, Ltd.

James B. Hess, formerly a metallurgist at the Institute for the Study of Metals at the University of Chicago, is now a research metallurgist with Kaiser Aluminum & Chemical Corp., Spokane, Wash.

Leonard G. Joseph, formerly metallurgist with the Midland Works of Crucible Steel Co. of America, is now working in the container metal quality department of the United States Steel Research Laboratory, Pittsburgh.



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These are two type 304 stainless steel blanks—1¾" thick and 22$^{5}/_{16}$" in diameter—rough machined and powder cut to pattern by G. O. Carlson, Inc. The dotted lines indicate where each blank was abrasive cut to produce two identical segments—the form in which dozens of these blanks were shipped to our customer.

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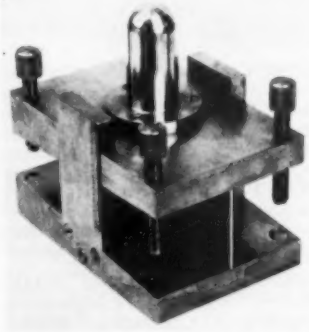
Free Cone Bend Test*

TO OBTAIN quantitative indication of the bending capacity of sheet material it is necessary to determine the smallest radius to which it can be bent without cracking. An approximation of this value may be obtained with the conventional types of apparatus by bending successive test pieces to progressively smaller radii, but if small differences in ductility are to be detected the differences in the radii of the formers or bending pins must be correspondingly small. The evaluation of a single sheet or coil may, therefore, involve the preparation and testing of a considerable number of test pieces. A further disadvantage associated with this method of evaluation is that the limiting radii of bend values obtained depend to a considerable extent upon the type of apparatus employed and the method adopted of maintaining intimate contact between the test piece and the former.

A free cone bend test was designed to determine the limiting radius of bend in a single operation, and since the region of the test piece undergoing deformation is not restrained, errors due to frictional effects, or local decreases in curvature are eliminated. The apparatus



Bending Jig With Test Piece in Place

consists of an upper and lower steel platen; attached to the lower platen are two rectangular guide members on which the upper platen is free to slide vertically. *(Cont. on p. 842)*

*Abstract of "A Free Cone Bend Test for Aluminum Alloy Sheet and Coil", by W. Thompson, Report No. A.I.D./MET/9, Aeronautical Inspection Department, Harefield, England.

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The Silvaloy joints produced are clean, strong and leakproof. Life tests for corrosion have been made and all reports assure prolonged, trouble-free service.

Silvaloy #355 is the only silver brazing alloy with properties and characteristics required for this operation. It has enabled this manufacturer to maintain a profitable rate of production and reduce drastically the percentage of rejects to an extremely low figure.

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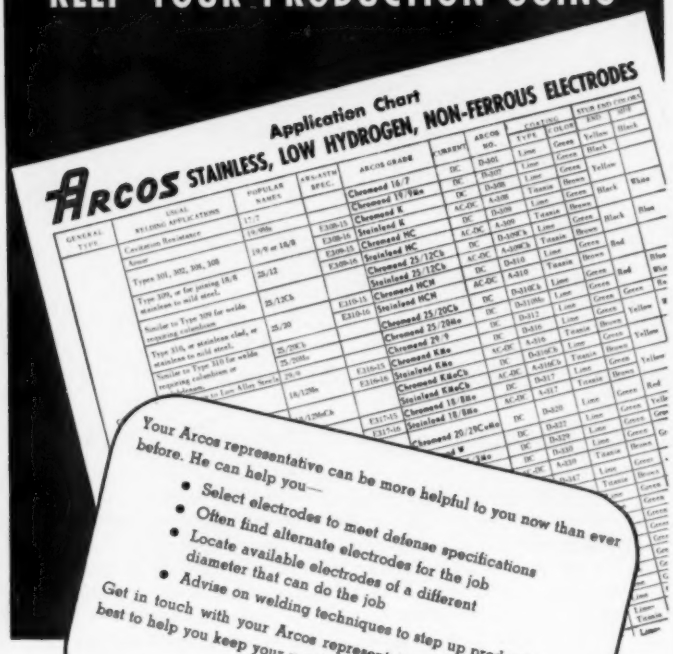

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Bend Test

(Cont. from p. 840) The platens are tapered and so disposed that the perpendicular distance between their inner faces increases progressively from one end to the other. There is a small semicircular groove running longitudinally through the center of each of the inner faces, and four adjustable screw stops are provided to arrest the downward movement of the upper platen in any desired position. Pressure is applied to the upper platen through a shank attached to its upper face, and the distance through which it has moved may be measured at any stage of the test by reference to a scale attached to one of the guide members.

The test piece, which is in the form of a trapezium, is mounted between the platens with its converging edges resting in the semicircular grooves. Pressure is applied to the upper platen, and after the buckling load of the test piece has been passed, it begins to bend symmetrically about its longitudinal axis, the central region taking up the form of a hollow cone with the radius of bend increasing progressively from one end to the other. When the radius of bend at the narrow end of the test piece becomes too small for the material to withstand, a crack develops and extends along the test piece to the point where the radius is just sufficiently large to allow satisfactory bending. The radius at this point is the limiting radius of free bending and may be measured by means of radius gages.

When the tests are being carried out for ductility comparison purposes, the scale reading at which cracking occurs is noted, and the screw stops are set to ensure that subsequent test pieces are bent exactly the same. Extremely small variations in ductility may be detected by measuring the lengths of the cracked portions of the test pieces. For example, the ductility of test pieces from the same sheet of material was varied by prestraining them in tension by different amounts. The limiting radii of bend values of adjacent test pieces were sensibly the same but the differences in ductility are reflected in the differences in the lengths of cracked portions.

The initial experiments with this apparatus were confined to aluminum alloy sheet materials, but subsequent work indicates that it may prove of value for acceptance and investigatory tests on other metallic and nonmetallic sheet materials.

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Continuous Stainless Strip Annealing and Descaling Line; Salt Descaling Bath and Water Spray Booth.

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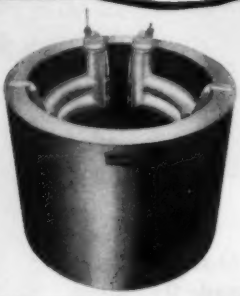
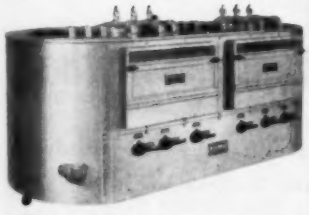


44" pot with 10,000 lb. capacity.
Casting rate: two tons per hour.
Estimated fuel savings of up to 40%.



Newspapers report actual savings of from 50% to 60% on fuel with 10-ton capacity melting pot shown above.

SAVE YOU UP TO 40% ON FUEL ALONE

If you melt soft metals, lead, pewter, tin or salt, you can now cut your melting costs to rock bottom. Actual cases prove that modern Kemp Gas-Fired Immersion Heating cuts fuel bills up to 40% and more. Reduces heat recovery time to 1/3—assures high thermal efficiency for both large and small units.

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There's no brickwork to steal heat—no external combustion chamber — no carbon monoxide—no temperature overrun. You get high melting rates, reduced dross formation and speed of temperature recovery after adding cold material. The Kemp Industrial Carburetor, part of each installation, assures complete combustion—reduces installation costs.

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Brass and Bronze Foundry Methods*

ESSENTIAL information governing the production of good castings has been collected from reliable sources and brought within the covers of a small and convenient booklet which provides a handy reference for the engineer who uses castings and the foundryman who makes them. The publication does not supply new facts or methods but rather a careful compilation of data scattered throughout the numerous writings on brass and bronze as they have appeared under the various specification bodies and technical journals. The personnel of the over-all and special committees is the best recommendation for acceptance of the material provided. The important warnings as to procedure confirmed by a reliable body of men acting together are a distinct advantage to the user of this information.

A few examples of such confirmed information, which covers 87 pages, will be given in this review. No test bar can be designed that will give accurately the quality of metal in any particular section of a casting. Applied research which is being undertaken at the present time may bring changes in the accepted test bar designs. As to mold wash, 85% of the foundries circularized used plumbago or graphite as a wash. Clay balls in natural sand are inimical to good molding. The cure is the mulling of such sand with some sharp sand. A mixture is given for dry sand and green sand cores.

Melting practice for alloys containing expensive metals such as chromium or beryllium should provide for the deoxidation of the melt before such additions are made, otherwise the chromium and beryllium will do the deoxidizing at their own expense. A figure of 85% is given for beryllium and 60% for chromium recovery.

In the information given under the subject of risers, the advantage of atmospheric pressure is emphasized but attention is drawn to the fact that, under certain conditions, gas pressure from within the mold may enable a blind riser to act effectively.

(Continued on p. 846)

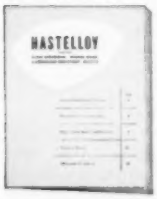
*Review of "Process Control of Brass and Bronze Foundry Procedure", compiled by the Non-Ferrous Metals Technical Committee, Society of Automotive Engineers, Inc.

handles *Boiling HCl* for 2½ years!

This HASTELLOY Alloy Condenser is still on the job in 1-10% Acid Solution

This condenser, made of HASTELLOY alloy B, shows no signs of corrosion after two and one-half years in a vacuum still for the distillation of hydrochloric acid. Since it was installed, the unit has been in operation two to three days a week, eight hours a day, handling a dilute solution of the corrosive acid at temperatures up to the boiling point.

HASTELLOY alloy B is one of the few commercially available materials that can handle boiling hydrochloric acid—one of the most severely corrosive agents known to the chemical industry. Alloy B is available in all standard wrought forms and can be fabricated by most common methods. Two additional HASTELLOY alloys, designated as C and D, are also available for handling other highly corrosive chemicals, such as sulphuric acid and certain strong oxidizing agents, like ferric chloride and wet chlorine.

The 28 in. tubes in this condenser for the distillation of hydrochloric acid are made from ½-in. diameter, 16-gage welded tubing of HASTELLOY alloy B. The end disks, which are ⅜ in. thick by 7 in. in diameter, are also of the nickel-base alloy.

For complete information, write for the 40-page booklet, "HASTELLOY High-Strength, Nickel-Base, Corrosion-Resistant Alloys." It contains data on the properties, available forms, and fabricating techniques for all three grades of HASTELLOY alloy.

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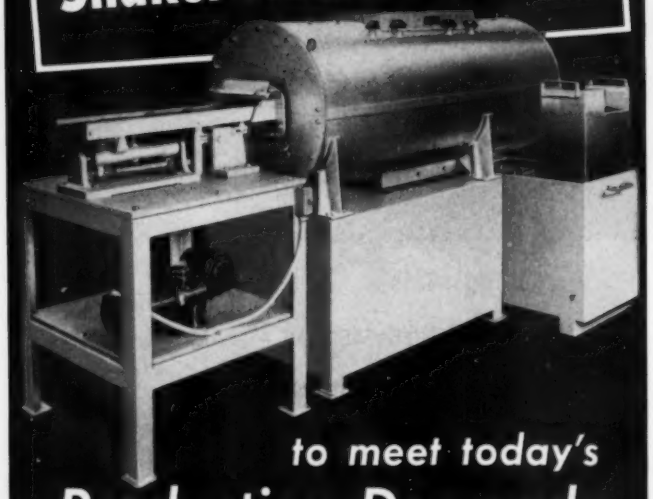

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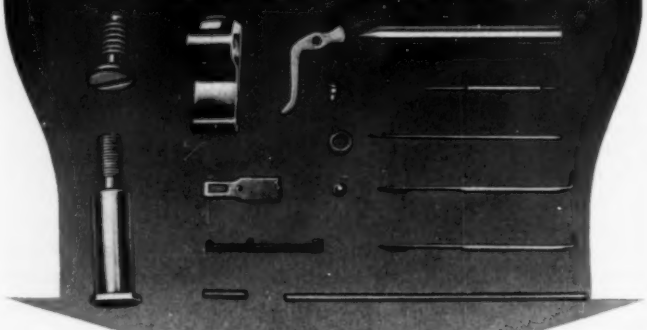

Hevi Duty Shaker Hearth Furnaces are used to bright carburize, bright dry cyanide or bright harden these small parts without distortion. Shaker Hearth furnaces process up to 150 lbs. per hour. Case depths are accurately controlled, and results are uniform. Learn more about this versatile Hevi Duty furnace.

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Brass and Bronze Foundry Methods

(Continued from p. 844)

A useful reminder is given that a "squeeze machine" produces molds that are hardest at the squeezer board and softest next to the pattern; the jolt machine produces an opposite effect so that the molds are hardest next to the pattern. From this, the advantage of the jolt-squeeze machine can be deduced.

The effect of vertical and horizontal casting is discussed in the section devoted to centrifugal casting. Figures are given showing the segregation due to centrifugal force and these figures show that lead is the only metal very much affected. Figures comparing physical constants of static and centrifugal casting for five representative alloys are given. Centrifugal casting in chill molds may give as much as 40% higher figures for some physical properties. The comparative merits of iron, steel, copper, and graphite for centrifugal molds are discussed. Graphite is said to compare favorably with iron as to cost, although it damages more easily. The trouble in centrifugal casting of tin bronzes in permanent molds is discussed with special reference being made to the holes that are often found to be present. It is believed that this trouble is related to the wider solidification range of tin bronze as compared with that of the brasses. The application of a suitable wash for coating the mold is suggested as a remedy because the slowing up of the solidification helps the gases present to escape while the metal is still molten.

Under "Die Casting", an analysis is given of a suitable steel for the dies. A very complete description, including melting points and casting temperatures, is given of five suitable die-casting alloys. Casting in the entirely liquid state is preferred to the use of the "mushy" condition, as the latter is more likely to hold entrapped gas.

Attention is drawn to the fine tolerances possible with the plaster mold method for casting brass and bronze — 0.01 in. being common practice, while 0.005 in. is easily maintained in many cases. The slower cooling rate due to the insulating nature of the mold material lowers the physical properties of leaded bronzes. In this connection, lead should not exceed 2.5%. Small

(Continued on p. 848)

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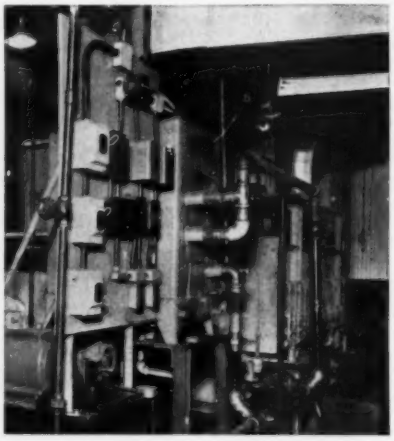

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Brass and Bronze Foundry Methods

(Continued from p. 846)

amounts of beryllium, aluminum, or silicon give finer surfaces and they are recommended for those castings where their use would not be detrimental. A very careful comparison, which covers 14 characteristics, is made of plaster of paris, sand, die, and permanent mold casting. The fact that the relative merits of the four methods were passed upon and agreed to by several manufacturers in these fields gives weight to the results.

Under the section "Reclamation of Castings", a comparison is made of three welding processes—namely, oxy-acetylene, metal and carbon arc, and heliarc, for use with seventeen alloys.

HAROLD J. ROAST

Welding Armored Vehicles*

WHILE the welding of low-alloy structural steels is relatively simple, high-alloy steels employed for armor present a more difficult problem because the critical cooling rates are far too low to prevent serious hardening without the use of prolonged preheating or postheating periods. The development of an austenitic 18% Cr, 8% Ni electrode for the welding of alloy steels made possible the welding of armor structures. A practical weldability test for armor and suitability of electrodes is described and some of the factors influencing weld cracking are reviewed.

The results of cold cracking tests revealed that for each group of steel the carbon content has an appreciable influence on the cracking tendency, and practical experience showed that steels having up to 0.35% C could be satisfactorily welded with an austenitic electrode without preheating, whereas steels having 0.35 to 0.46% C could be welded satisfactorily if preheated from 100 to 150° C. It was also found that resistance to cold cracking may be influenced by the steelmaking practice. *(Cont. on p. 850)*

*Abstract of "Evolution of Welded Armored Fighting Vehicles", by Major R. J. Fowler and Major L. F. Denaro, *Transactions*, Institute of Welding, June 1946, p. 87-93 and August 1946, p. 115-127.

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Trouble-free, built-in ease of fabrication with Superior Stainless Strip means faster, smoother production with fewer rejects . . . and that means money to the mouldings manufacturer. There are definite reasons why: let us demonstrate them!

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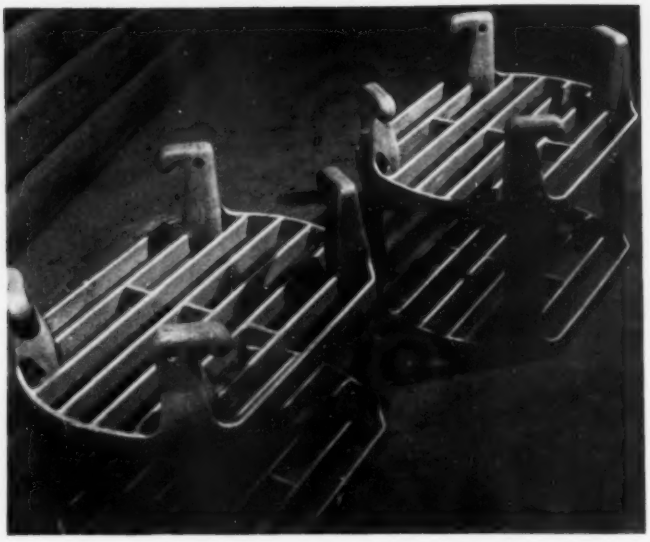

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Note the uniformity of sections throughout entire casting with special tubular lifting eyes as an integral part of the fixture to facilitate handling.

Quality castings, in which sound engineering fundamentals are incorporated, plus — quality control from pattern to finished casting and engineered foundry technique — offer our customers greater savings in operating costs.

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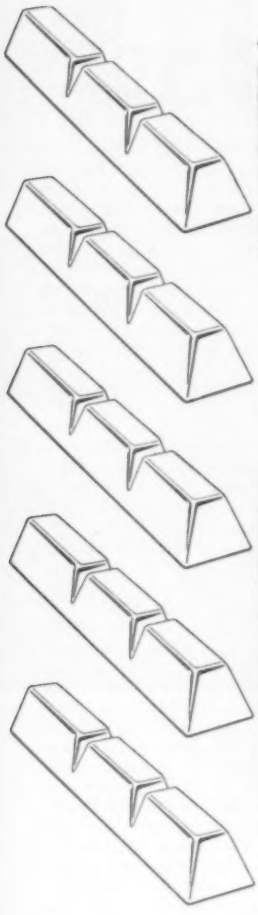

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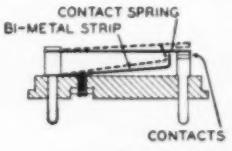
CHACE BIMETAL
Keeps Them Home on the Range!

Stevens Type "C" Thermostat (shown full size) Manufactured by Stevens Mfg. Co. Mansfield, Ohio (Patent applied for)

TELEVISION plays a big part in keeping the "small fry" at home these days, and this Stevens Type C thermostat helps keep their favorite programs on the video screen. Actuated by Chace Thermostatic Bimetal, the thermostat is used in communications equipment, electronic devices and other apparatus requiring a high degree of temperature stability.

In its television and radio application this thermostat maintains a constant ambient temperature around the quartz crystals which control transmitter frequencies; this prevents variation in these frequencies. Since it is essential that the thermostat respond only to the temperature of the device it controls, an *electrically independent* strip of Chace Thermostatic Bimetal forms the actuating element. Current flows through the stainless steel or alloy spring, but does not pass through the thermostatic bimetal. As the bimetal element responds to a predetermined ambient temperature it overcomes the spring pressure and opens the contacts. This assures a sharp, clean break and eliminates artificial cycling or life-shortening "jitters."



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Welding Armored Vehicles

(Continued from p. 848)

The ease with which heavy rolled armor and armor castings could be welded was determined with a small-scale test known as the Reeve fillet weld test. The effects of preheating deep hardening steels are pronounced, this being due to the retardation of the martensitic transformation. The difficulties encountered in translating the results of small-scale tests to full-scale production welding are recognized.

Metallurgical examination of armor assemblies fabricated to correlate behavior under ballistic attack, cracking, hardness of heat-affected zone and weld metal, confirmed the necessity for limiting the carbon content of heavy plates and revealed that the root runs of welds are subject to substantial dilution from the parent plate. This dilution may be important in equipment subjected to applied stress, and may be responsible for the propagation of cracks in welded joints.

Advantages of austenitic electrodes and the Hopkin theory of hydrogen's influence on cracking (see "Welding of Armor", *Metal Progress*, April 1951, p. 580) are reviewed. The influence of hygroscopic moisture in electrode coatings on cracking was emphasized. Atmospheric humidity and potential hydrogen content of the electrode coating coupled with the efficiency of the drying operation will determine the amount of moisture present.

The analysis range for armor to be welded by ferritic electrodes was determined for two grades of steel (Ni-Cr-Mo and Ni-Cr-V). Cracking in the latter was caused by the formation of a band of ferrite and martensite toward the outside heat-affected zone. Development of a mild steel electrode with rigidly controlled hydrogen content in the coating resulted in sound joints in alloy steels which had formerly required austenitic electrodes. Tests on selected low alloy high tensile steels (Cr-V, Mn-Ni-Mo, Mn-Ni-Cr-Mo) proved that these grades could be welded with commercial ferritic mineral-type coated electrodes. Stud welding and gas cutting of armor are described. The second part of the article gives a general description

(Continued on p. 852)

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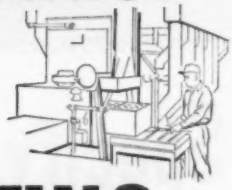

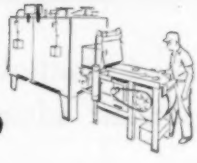

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Welding Armored Vehicles

(Continued from p. 850)

of the growth of welding armor in the production of tanks and armored cars. Factors which determine the types of welded joints, the practical welding methods used in production, as well as jigging and manipulation for welding are described. It was shown conclusively that, due to the difficulty of temperature control in large assemblies, the postheat treatment was likely to degrade the ballistic properties of the plates and was therefore eliminated. Plate cleanliness prior to welding is highly important.

Special welding techniques used in the fabrication of the Cromwell, the Churchill and the Valentine tanks are explained. It was concluded that welded construction may save up to 20% in man-hours, 4% in weight but requires 50% more fabricating space.

HANS J. HEINE

Vacuum Fusion*

THE paper represents a most systematic and logical approach to the problem of the effects of carbon, nitrogen, oxygen and hydrogen upon the most important characteristics of ferrites containing 25% chromium (which are known in the United States as chrome-irons) plus a brief excursion into the domain of higher chromium alloys (30% Cr). All steps of the experimental work were repeated a number of times to eliminate accidental conclusions. The only drawbacks this reviewer could notice were: *(a)* the use of too small amounts of the metal (of the order of 300 to 500 g.), *(b)* the absence of determinations of densities and electric conductivities. Of the latter, the author probably could make no use, due to the small amounts of the alloy fused and to the absence of proper facilities, but the absence of density data forms a rather unfortunate habit with most research metallurgists and hardly can be excused.

Intergranular brittleness is far more likely to be due to the rejec-

(Continued on p. 854)

*Abstract of the thesis, "The Influence of Vacuum Fusion Upon the Characteristics of Ferrite Containing 25% Chromium", by J. Hochmann, University of Paris, 1950.

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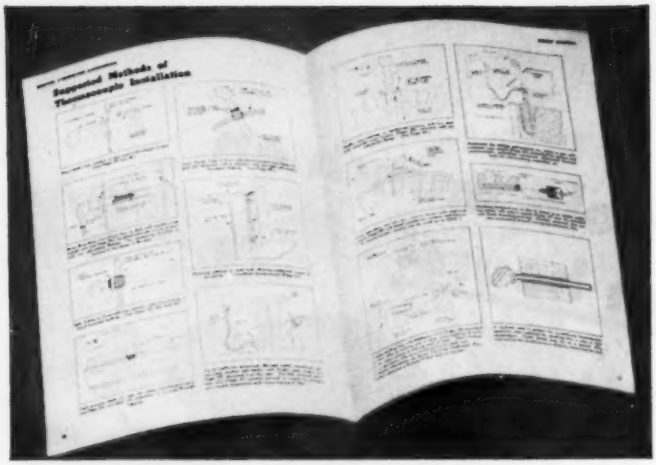

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Vacuum Fusion

(Continued from p. 852)

tions of gas films to the grain boundaries than to the presence of carbides or nitrides, and density determinations, which can be relied upon to be precise to 0.0002 of the total figure, would easily detect them. Besides, the smallness of the sample, while not affecting the theoretical value of the results obtained, must give rise to grave doubts regarding the practical application of the method. The liberation of the three noxious elements in the gaseous phase depends greatly upon the pressure exerted by the metal, and a bath of the latter that is 20 in. deep might prove a tremendous obstacle to degassing.

The technique used consisted, in part, in the remelting in vacuum of machined samples of industrially produced chrome-irons in order to see how vacuum fusion affects the chemical composition and the characteristics. In the next and much larger program of work the heats were synthetic, involving the separate introduction of carbon, nitrogen, and oxygen. Some tests were made on the solidified metal, others after it was reduced to square rods of 5 to 7 mm. side.

Unfortunately, not every detail of the experimental procedure is clear enough. The author speaks of "coulee a vide" meaning vacuum-casting, but the construction of the apparatus with its resistor of a spiral of graphite does not indicate the feasibility of a transfer of the molten metal to an ingot mold, nor the possibility of doing it by opening the vacuum vessel. It must be assumed that the metal was always allowed to freeze in its crucible.

The crucibles were made of beryllia, alumina or magnesia. Obviously, only the latter might be considered in the application of the research results to practical use. In each case the carbon content was decreased to 0.002 from 0.030% and at least 90% of nitrogen was always eliminated. But, the oxygen content would not drop below 0.01% in magnesia crucibles whereas it was practically eliminated in the other two. The cause for this was attributed to a part of the carbon being oxidized in contact with magnesia thereby leaving some of the metal's oxygen unused. Chromium content was lowered by 0.5%, due to vacuum distillation, and manganese was also practically

(Continued on p. 856)

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Vacuum Fusion

(Continued from p. 854)

eliminated for the same reason. Vacuum fusion did not eliminate hydrogen.

In the synthetic heats, carbon was introduced in the form of synthetic pig iron which was placed in a hole drilled in the iron charge. This method did not work in magnesia crucibles; all carbon was oxidized and eliminated entirely by the reducing magnesia. About 0.04% was introduced using the other two kinds of crucibles.

Oxygen was introduced by providing a lining of chromium oxide. Up to 0.05% could be obtained in this way. Nitrogen and hydrogen were introduced as gases following a thorough degassing. Up to 0.05% of the first and up to 10 cc. per 100 g. of the second were found in the alloys so treated.

The first important finding was that ordinary chrome-iron is by no means a permanently ferritic alloy. Vacuum-melted and then quenched from 1472 to 2192° F., it possesses a constant tensile strength of 70,000 psi., but, without that remelting, its tensile strength was a rising function of the temperature of prequenching, reaching 125,000 psi. when the sample was quenched from 2192° F.* Apparently, either of the three elements present (carbon, nitrogen, oxygen) can produce a certain amount of austenite-yielding martensite on quenching.

Of the synthetic heats, each containing only one of the four elements examined (carbon, oxygen, nitrogen, hydrogen), all behaved as ordinary chrome-iron when quenched from 1652° F. Quenched from 2192° F., all displayed a lowered elongation. However, the latter was badly impaired only in the case of carbon, and only carbon produced a considerable increase in the tensile strength.

Ordinary chrome-iron has a poor impact strength which cannot be improved by heat treatment. Remelting in vacuum, using beryllia or alumina lining, *(To p. 858)*

*All static tests were made with a Chevenard micro-testing machine on samples 0.058 in. (1.5 mm.) in diameter. Elongations would be dropping from 30 to 5% average if not remelted in vacuum. When samples were remelted, the elongations were hardly affected by quenching, staying around 25%, though figures as high as 40% were obtained on samples fused in alumina or beryllia and quenched from 1652° F.

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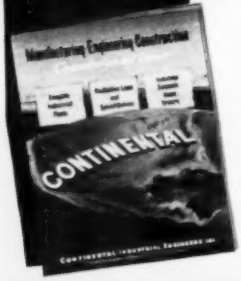

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Vacuum Fusion

(Continued from p. 856) results in a metal of excellent impact resistance immune to heat treatment and quenching from above 1652° F. Even the crucible frozen metal had a very high impact resistance, at least as good after quenching from 1652 as after 2192° F. *This indicates that grain size has no effect upon the mechanical characteristics of chrome-iron, a contention which this reviewer maintained for years to apply to all mechanically pure metals and alloys.*

However, vacuum remelting in magnesia crucibles resulted in but little improvement of impact strength. Synthetic heats made in alumina have shown that all four of the undesirable elements affect badly the impact resistance of samples quenched from 2192° F. — the effects of hydrogen being irregular while those of nitrogen are relatively less pronounced. The impossibility of eliminating all oxygen, or even a considerable amount of it, when melting in magnesia explains the poor impact strength of samples so obtained.

Although melting in magnesia cannot eliminate oxygen to a desirable extent, its advantage over alumina or beryllia is that carbon can be eliminated even at a relatively low vacuum of 1 mm., whereas refining in alumina is a very slow process even at a vacuum of 0.001 mm. When the amount of oxygen present is not too high to begin with, the samples so prepared in magnesia possess a relatively high impact resistance (about 50% of the possible maximum). These facts were found to be valid also for a 30% chromium alloy. Remelting in magnesia at 1 mm. pressure produced a metal with a carbon content of 0.003% and with a very high impact resistance whether it was quenched from 1652 or 2192° F. — again the unimportance of grain size was definitely established.

Vacuum fusion executed in magnesia in contact with large amounts of carbon (0.1 to 0.2%) resulted in a nearly complete elimination of the carbon and a thorough reduction of nitrogen and oxygen. Samples so made had a high impact resistance, irrespective of the prequenching temperature.

Vacuum fusion was found to have an enormous effect upon the notch sensitivity of the 25 and 30%

(Continued on p. 860)

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Vacuum Fusion

(Begins on p. 852)

chromium alloys. As processed ordinarily, the alloys have no notch resistance at normal temperatures although they exhibit a continuous improvement at higher temperatures up to 572° F. Vacuum-fused alloys are immune to notch effect down to 4.5° F., though they are definitely notch-sensitive about −112° F. and perhaps even at somewhat higher temperatures. The transition temperatures (from ductility to fragility) are shifted by vacuum fusion by some 400° F. downward.

General corrodibility of chrome-irons quenched from 1652° F. changes but little with vacuum fusion, nor is it affected much by added impurities of nitrogen and hydrogen. Only higher amounts of oxygen and additive carbon increase the rate of the attack in nitric acid and cupro-sulphuric reagents. The situation changes greatly with quenching from 2192° F.; all impurities, natural or intentionally added, rapidly accelerate corrosion by way of intergranular attack. But, the vacuum re-fused alloy behaves identically for the 2192° F. quench as for the 1652° F. quench showing no intergranular corrosion. Here again the grain size plays no important part in the mechanical characteristics and therefore serviceability of the pure alloy.

Because the above indicates that the general deleterious features of notch sensitivity and intergranular corrosion are due, strictly, to the action of impurities, vacuum melting in the presence of extra carbon on a magnesia bottom could make an industrially useful method of improving the alloys. The author tried also to determine whether vacuum fusion could eliminate or change the slowly growing embrittlement caused by a sojourn in the 752 to 932° F. range, and especially at 887° F. In this respect, the conclusions derived by the author, and such as are derivable from his tabular data, are as follows:

The embrittlement in this range is an unavoidable physico-chemical process based upon the formation of the sigma phase. As pointed out by Newell, its appearance usually causes a distinct increase in Rockwell C hardness, from 22 after 20 hr. to 33 after 5000 hr. The author studied only the effects of the 100 and 300-hr. holds at 887° F. after quenching from 1652 and 2192° F.

He found that samples quenched from 1652° F. harden rapidly and develop a tensile strength of 140,000 psi., and an elongation of less than 15%. On the other hand, samples quenched from 2192° F. did not harden at all and, if they contained no oxygen, remained at 65,000 psi. and 25% elongation.

However, notch-impact tests have shown that in spite of the static stability obtainable in metal purified of carbon, nitrogen and oxygen, there was no improvement in notch sensitivity after a stay at 887° F. This sensitivity begins to appear at a sojourn at 572° F., persists from 752 to 887° F. at its maximum, and slowly decreases until the full dynamic stability is recovered at 1472° F. Again intergranular corrodibility, specific for samples that were held in the 752 to 887° F. range, is encountered even in the vacuum-purified alloys.

A further advantage of vacuum re-fusion is the metal's increased life at high temperatures when it is subjected to periodic heating and cooling. Ordinary alloys, as well as those that were fused in vacuum but contained added impurities, showed a rapid oxidation after 1 to 3 alternations; the purified alloys oxidized quite slowly up to 8 to 14 alternations, and even after that the accelerated oxidation did not proceed so fast. It was found also that a thorough degassing of the solid metal (wires) in a vacuum results in a great increase in the life of the wire. The author discusses the theoretical aspects of oxidation as developed by other investigators.

The paper carries 26 micrographs plus two macrographs and one fractograph. These show that the vacuum-made pure alloys quenched from 1652° F. represent a practically perfect single phase, while those quenched from 2192° F. show chains of fine particles along the grain boundaries. Neither temperature group shows any precipitate or inclusions inside the grains. On the other hand, ordinary-air fused alloys always show precipitates and inclusions, the precipitation being most severe in samples quenched from 2192° F. and annealed at 1292° F. Samples carrying intentionally added nitrogen or oxygen show inclusions at the grain boundaries, but apparently no precipitate.

In short, Dr. Hochmann seems to have proved that many defects of the chrome-iron alloys containing 25% or more chromium are due to impurities, which might be elim-

(Continued on p. 862)

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Norman S. Mott
Chief Chemist and Metallurgist

Alloy type 25-12 (CA22) is mainly a heat resisting alloy, although in the low carbon grade, with or without columbium or molybdenum, it is often used for its corrosion resistance. It is the most economical alloy for high temperature structural applications, such as tube supports, dampers and general furnace parts. In gas carburizing and bright annealing or hardening atmospheres its resistance is excellent and its resistance to high temperature air oxidation and to the corrosive action of high sulfur fuel flue gases is outstanding.

The 25-12S, 25-12SCb and 25-12SMo grades give excellent service in the sulfite pulp industry; and offer high resistance to nitric, phosphoric, dilute sulfuric and hydrochloric acids, as well as to organic acids such as citric, tartaric and lactic. 25-12S has better corrosion resistance than 19-9S, with carbon not being so critical. This holds for use in dilute sulfuric and hydrochloric acids at all temperatures, and in nitric acid at all concentrations and temperatures. In fact, in the boiling 65% nitric acid test 25-12S as cast is as good as 19-9S in the water quenched condition. The addition of molybdenum makes this alloy remarkably resistant, and its superiority in hot dilute sulfuric and hydrochloric acids over 19-9SMo is considerable. This suggests its use over 19-9SMo in some of the more exacting applications not necessitating the use of expensive FA-20 type alloy.

A.S.T.M. Specification B190-45T classifies the 25-12 alloy into two categories according to magnetic permeability: Type I, having a range of 1.05–1.7, and Type II, having a maximum of 1.05, after holding for 24 hours at 2000° F and water quenching. Since strength and ductility vary inversely at high temperatures, Type I containing ductile ferrite is able to resist fracture due to sudden overloads by yielding slightly under these stresses, but it has relatively low creep strength. Type II is completely austenitic and has high creep strength under conditions of constant loading, but is not as resistant to sudden shock.

Of major importance in heat applications is the influence of structure on its properties. The amount, form and distribution of the carbides affect strength and ductility and are determined by the percentage of carbon present in the alloy, the temperature, and the time of holding. Of perhaps greater importance is the presence of ferrite in the structure. While it enhances ductility at elevated temperatures after short-time aging, it must be discounted if the alloy is to be exposed for extended periods at the intermediate temperature range of 1200–1700° F, as this range favors the formation of a sigma phase which is hard and brittle. Its presence may result in reduced strength, ductility, and especially thermal fatigue cracking resistance. Thus there is much less tolerance for suddenly applied stress overloading or rapid temperature changes. Continued service about 1700° F. precludes this sigma formation.

To estimate ferrite on the basis of chemical analysis the Alloy Casting Institute suggests the following formula:

$$\text{R.F.} = \frac{[\%\,\text{Cr} + 3\,(\%\,\text{Si} - 1)] - [\%\,\text{C} \times 16]}{\%\,\text{Ni}}$$

A ratio factor less than 1.7 denotes a negligible amount of ferrite or sigma and corresponds to the A.S.T.M. limit in permeability value of 1.05. A ratio factor of 1.7–1.85 denotes 2–7%, and a ratio factor above 1.85 denotes above 7% of ferrite or sigma.

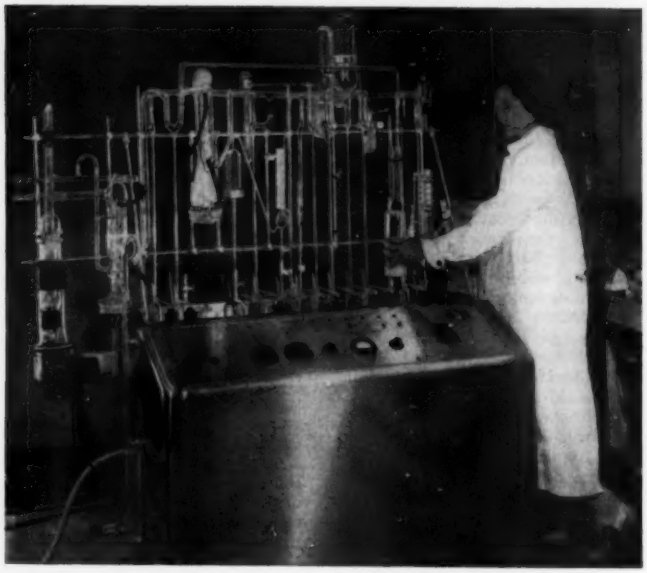
Available on request

Cooper Alloy Materials Selection Chart — designed to help you choose the most economical alloy for any corrosive condition. This chart will save you money and save critical materials for national defense. Address your requests to Publicity Dept., The Cooper Alloy Foundry Co., Hillside 5, N. J.

COOPER ALLOY
Stainless Steel
VALVES · FITTINGS · CASTINGS

NEW

Vacuum Fusion Gas Analyzer...



A packaged unit to determine the content of oxygen, nitrogen and hydrogen in metals

A wide variety of metals and alloys, including titanium, can be analyzed to determine the amount of oxygen, nitrogen and hydrogen contained either as combined or dissolved gas, in the range from one per cent to approximately 10^{-4} per cent by weight.

The apparatus incorporates the best features and techniques reported in the literature or known to our laboratory and has been employed for some time in connection with our own metallurgical research activities.

Operating procedure is relatively simple and can be readily mastered. Installation and final testing is performed by one of our trained analysts.

Write for details of Type 09-1240 Vacuum Fusion Gas Analysis Apparatus.

TITANIUM

Total gas contents are reported within approximately the same range as for other metals, through the use of certain special techniques.

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Vacuum Fusion

(Continued from p. 861)

inated to a very high degree by vacuum fusion and vacuum treatment. Of these impurities only hydrogen escapes the action of the vacuum, but it has a relatively slight negative effect. The defect of impaired dynamic stability and of an increased intergranular corrodibility caused by a sojourn at 887° F. seems to him to be unavoidable, though it is the only one inherent to the basic composition.

This reviewer would add that it might be of great interest to know the state in which the nuisance elements exist when the metal is embrittled. So, one might expect carbon to form either intergranular chains of carbides, bubbles of carbon monoxide, or both. Density determinations could provide the answer. As to the brittleness due to the sojourn at 887° F., and certainly due to an FeCr compound, the explanation apparently is that in the solid solutions both atoms are essentially cubo-octahedral bodies which can slide along the slip planes fairly easily. The FeCr compound, on the contrary, must represent a combination of a large cubo-octahedron of chromium with a much smaller near-octahedron of iron. The gliding of molecules so complicated in shape must be a more difficult process. In a static test the time factor is great enough to let it take place whereas in a notch impact test there is no time for this gliding. M. G. Corson

Aging of Al-Cu-Ti Alloys*

RECENT work in England on the solubility of tin in aluminum has shown that it has a slight solid solubility of the order of 0.05% at 985° F. and has a very low value at 330° F. Binary aluminum-tin alloys imparted a considerable age hardening effect when artificially aged after solution heat treatment. The proof-stress values were higher as compared with those obtained in

(Continued on p. 866)

*Abstract of "The Effect of Small Quantities of Cd, In, Sb, Tl, Pb, or Bi on the Aging Characteristics of Cast and Heat Treated Aluminum–4% Copper–0.15% Titanium Alloy", by H. K. Hardy, *Journal of the Institute of Metals*, Vol. 78, Part 2, 1950.

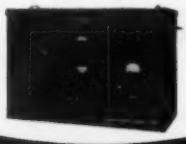
Close Control of
HEAT

It is at the very large research laboratories as well as at the numerous smaller ones, that the uniformity of heat maintained with Marshall tubular furnaces is commented upon. This uniformity over the entire specimen is assured not only by the correct spacing and secure anchoring of heating element coils on the refractory core, but also by means of zone-to-zone temperature adjustments with shunts attached to the taps along the outside of the furnace.

Send for Marshall circular describing Marshall Furnaces and Control Panels. Marshall Products Co., 270 W. Lane Ave., Columbus, Ohio.

MARSHALL

HIGH TEMPERATURE FURNACES
CONTROL PANELS



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M–30
JAN. 22, 1951
Here's the Answer...
CIRCLE M
Memo
TO---Users of High Speed steel
SUBJECT---Experience with Moly Steel
Firth Sterling has been known for years as a leading producer of the tungsten types of high speed steels. The tungsten steels Circle-C and Blue Chip are world famous and Firthite, sintered tungsten carbide, is used in metal working shops everywhere...
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METAL SHOW FACTS

NATIONAL METALS EXPOSITION

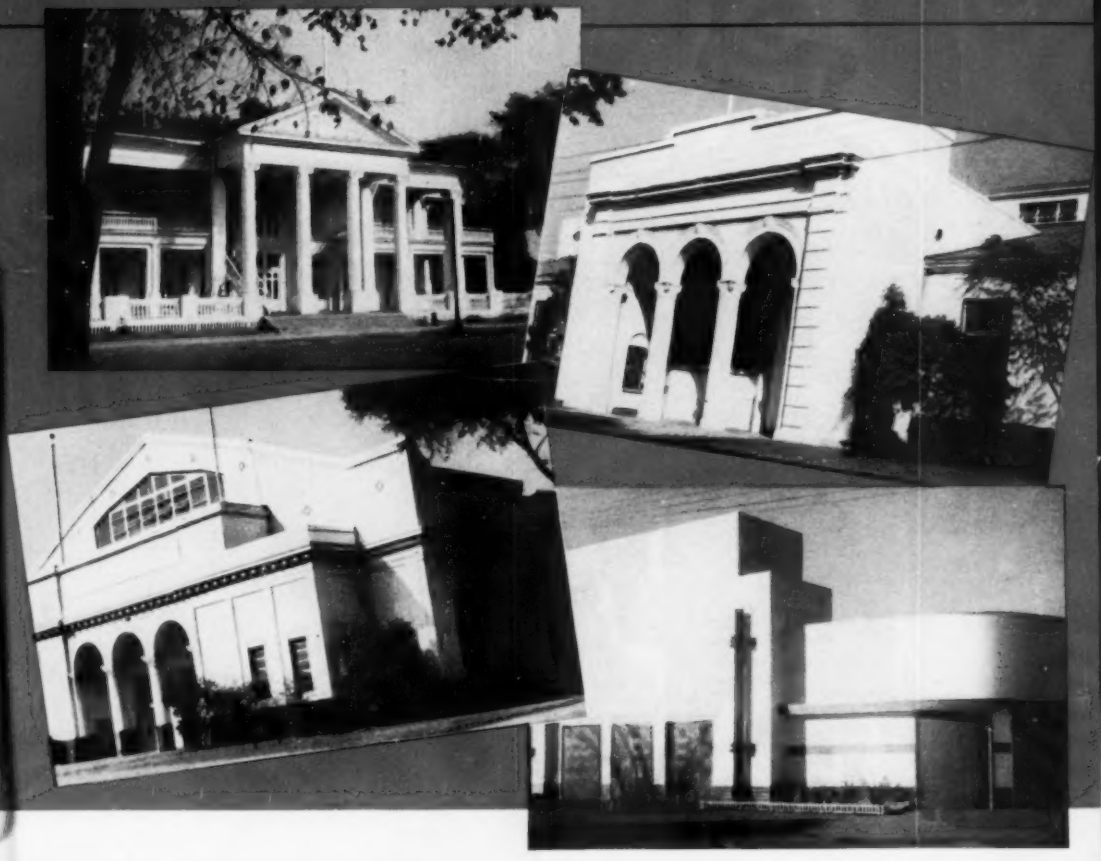
OCT. 15-19 · 1951 DETROIT, MICH.

Where Men and Metals Meet
. . . and
they both mean business!

SHOWING HERE SHOWS THE METAL WORLD

. . . what you make

. . . what your products can do



MICHIGAN STATE FAIR GROUNDS

The Michigan State Fair Grounds is located approximately 8 miles from the center of Detroit on Woodward and State Fair Avenues. Large parking areas are adjacent to the grounds for exhibitors and visitors. Exhibit areas are located on the ground level in all buildings. Deliveries of exhibit equipment can be made easily — direct to the halls by truck. Two railroad sidings for carload shipments are conveniently located to the Michigan State Fair Grounds.

Peak demand turns spotlight on

NEWER, FASTER, BETTER TECHNIQUES

Tightening controls and accelerated demand for defense requirements today focus national attention on metals, metals processing and the newer, faster, better techniques and developments that have been coming along quietly for the past several years.

Ready for introduction to all metals industries at the National Metal Exposition will be a score or more of brand-new time-saving, manpower-saving machines. Materials and processes that will quicken considerably the production pace of American industry.

Worth noting will be a simple, fast, fool-proof method of bonding silicone rubber to metal and ceramic surfaces . . . a method that provides a bond several times stronger than the rubber itself. There'll be an all-new easy-to-apply and easy-to-remove corrosion resistor that'll make the shipping of metals overseas and the storage of metal products anywhere in any climatic condition safe and simple. There'll be a hatful of new products and new processes to make the metal fabricator and the metal producer happier with his lot.

However, some of the larger producers and fabricators are keeping their plans for the National Metal Exposition about as secretive as the Manhattan Project was during the last world war. Can't blame them, because the excitement and interest generated by the heavy customer attendance at the Show is priceless to the outfit that can steal its share. Look for the new . . . the sensationally faster and better processes and equipment to stop the Show traffic and get off to high-geared acceptance right where the biggest concentration of metals industry buyers and users in many years will be . . . the Michigan State Fair Grounds in Detroit, October 15-19 inclusive.

Metal Show Fever is spreading swiftly . . . it's an easily identified ailment showing up in laboratories . . . sales meetings . . . engineering departments and around conference tables. The symptoms are excitement, feverish activity and great determination. The remedy is one large dose of exhibition space at the biggest, best and most enlightening Metal Exposition ever put together!

The all-metals show **FOR ALL METALS INDUSTRIES**

TOUGH COMPETITION PACES NEED FOR YEARLY METALS EXPOSITION!

LOOKING BACK OVER THE *"show-born babies"* THAT CLICKED

The old adage about the better mousetrap doesn't work today. Make a better mousetrap and a competitor will also make one and undersell you, at that. It's this kind of tough, get-that-business competition that keeps the metals industry on its toes and points up the need for a centralized, big-time national show every year. Only at such a Show can competition keep its fingers on the pulse of its national business . . . only there can men learn what they've got to do . . . and fast . . . to stay out in front.

Looking back over the years, the metals industries have witnessed the birth of some outstanding achievements and changes at the Shows . . . changes that forced other changes in processes and designs to stay abreast of the new and the more salable ideas. 'Way back in the early 20's Rockwell's original hardness tester was unveiled and it did a lot for all metals industries . . . and after it came an endless series of important developments . . . stainless steel, liquid carburizing, titanium, continuous heat treating furnaces, instruments, gauges. Alloys stole a number of Shows and lighter, easier-to-machine metals had their big innings. Better ways and faster ways of handling tonnages of almost everything that goes into metal production flashed across the Show stages.

That's one of the biggest factors in the year-in, year-out importance of the Shows. This year it'll be no different. It'll be big, important, dramatic. It'll whisk away the veil of secrecy from a sizable number of new things. It'll hammer home the idea that this nation's industries feed on metals . . . live on metals . . . grow and prosper and strengthen the military might of our country with vitalizing and invigorating new achievements in every phase of metal progress from mine to ultimate user.

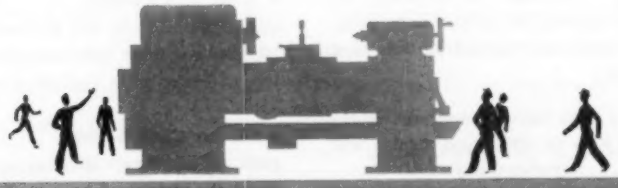
More than ever before, the men who work with metals are achieving their rightful place in the spotlight of national interest. It is true, of course, that the physicist, the chemist, the electronics engineer and others have made great contributions to our way of life and to its defense. But, the metals engineers have and are making strides of equal if not greater importance — and this year the Show will capture for the mill producer, the shaper and fabricator, the metals engineer and the metallurgist the full recognition so long overdue.

Double Check ON SHOW VISITORS *Proves*

BIG INTEREST IN ALL METAL FIELDS

If the words Metal Show could be changed to Metal Sales and Services, it would be a lot closer to the truth in connoting what goes on at this exposition featuring every phase of the metals industries. Metals Sales is a broad and unwieldy term, but the man who comes to the Show and sees a new piece of equipment that will help him shape, fabricate, or harden a piece of metal faster and better — he'll buy. The producer who sees new alloy specifications or bumps into a materials handling answer buys, too. This happens because the whole vast, basic metals industry sends men to these expositions who are double-dyed, think, talk, dream-about-metals folks.

Unlike a lot of other expositions, the Metal Show plays to only a scattered few casual visitors. The Metal Show is for metals men and the attendance has been double-checked to learn what metals people are going to be looking for — and at — come this October. The answers listed below are factual and informative.



THIS IS WHAT THOUSANDS WILL ASK TO SEE AT THE METAL SHOW

EXPECTED AT THE GREAT '51 SHOW — 45,000 UP!

1 out of 3 will want to see Abrasive Wheels and Materials

1 out of 5 will check Acetylene Cutting Equipment

1 out of 7 will be looking for Alloying and Refining Agents

2 out of 5 will study Alloy Steels

2 out of 5 will give Aluminum a close look

1 out of 4 will be interested in Brass and Copper

1 out of 3 will want to see Brazing Equipment

1 out of 2 will check on Furnaces, Heat Treating

1 out of 2 will have a look at General Shop Equipment

1 out of 3 will be interested in Ferrous Metals

1 out of 2 will be checking Testing and Inspection Equipment

1 out of 3 will ask about Materials Handling Equipment

1 out of 3 will check Protective Coatings

1 out of 2 will look for Welding Equipment, Accessories and Supplies

1 out of 4 will check Non-Ferrous Metals

1 out of 4 will ask to see Tool Materials and Tool Steels

1 out of 5 will want to know what's new in Lubricating and Cutting Oils

1 out of 3 will be interested in new Laboratory Equipment

1 out of 5 will want to know about Iron

. . . and that isn't all, by any means. Advance information proves that metals industry people will be curious about everything at the Show . . . and the curious are those who can and will be sold, right at the Show.

There's no Double-Talk in this Double-Check . . .

Registrations are the important count and the one that governs these reports, but sometimes, for insurance reasons, clickers are placed on the doors. This latter count is of no value but to owners of exhibition buildings. That's why it's made.

GOOD SHOWMANSHIP . . .

GOOD SALESMANSHIP

vital to every exhibitor

- ***Good Location*** . . . means a lot in getting the story of your products over, but it isn't everything. Even an ordinary space can be made to sell hard if it's handled right.

- ***Good Display*** . . . is just as important as the location . . . maybe more so, since good display will stop a lot of folks . . . anywhere, anytime!

- ***Motion and Color*** . . . are vital factors in good display. If it can possibly be done, show your products in use. Dress up your displays with bold colors, lots of light. They attract — but solidly!

- ***Facts always ready*** . . . don't fumble questions on the Show Floor. Have all the facts about your products and have every man on your floor fully schooled about weights, speeds, capacities and whatever else is pertinent.

- ***Alert salesmen*** . . . well, seems silly to point this one out but visitors notice a lot of men on the floor having fun instead of selling.

- ***Technical Knowledge*** . . . if you can't quickly tell a curious man how your product will fit into his present operation . . . or how it will help him over the long-haul . . . he won't be interested long. It's important to know the whole range of your own product's application!

- ***Good-Time Charlies*** . . . everybody has fun at one of these Shows, but the men who have the lasting fun are those who stick close to their specific jobs and take home with them some healthy orders.

- ***It's just Good business*** . . . and business is good at Showtime. Make as much noise as possible about the virtues of your products and keep everlastingly at the job of building up leads to follow after the Show closes. That's where the big business is done!

INFORMATION, *Please!!*

Keep your spec sheets, your data books and your literature always in easy reach and hand it out to those who spark even a mild interest in what you're showing. To many visitors, time is exceedingly important and you help them — and yourself — by giving them what they want quickly and pleasantly.

THE ALL-METALS SHOW FOR ALL METAL INDUSTRIES

INSTALLATION COSTS . . . FURNITURE RENTALS LABOR CHARGES, ETC. STANDARD IN BIG CITIES

Overtime and Opening Deadlines Force Costs up but Check of Many Shows Reveals Average Is Steady . . .

A pretty thorough check of some of the larger industrial shows that have been staged in "key cities" during the past year indicates that the big single cost factor is the overtime, the night work and the rush of getting exhibits set up and operating by opening hour. For example, a show opening at 11 a.m. on a Monday morning in a big eastern city forced this condition upon exhibitors. Because another show was going on in the auditorium, show No. 2 couldn't begin to move in until midnight Saturday. That meant that crews of workmen, truckers, electricians, painters and set-up men had to be held in readiness until midnight — at time-and-a-half wages.

It also meant that riggers and carpenters had to sit idly by at mounting wages until they could get to work. However, some of these men had to be paid double time because that's the way their union contracts were written. In still another town, all workmen involved in an overnight make-ready for a show were paid on a special rate that was pretty steep — but there wasn't any cure for that at the moment.

Metal Show exhibitors know they're protected always against these hurry-up, overtime-paying jams. ASM has never provided less than one full week for set-up — and this year you'll have TWO WEEKS to get ready. That kind of planning saves time, money and tempers.

WORLD METALLURGICAL CONGRESS TO HIGHLIGHT TECHNICAL ADVANCES . . .

From all the free countries of the world will come scientists and metallurgists for a series of scheduled meetings at which a broad interchange of ideas and projects under way will be discussed and weighed. This is the first time such a Congress has ever been assembled and it is certain to draw much attention from the business and industrial publications around the country.

Because it will be staged along with the Metal Exposition, the Congress will focus a long-needed spotlight on the men who work with metals, who develop and create and engineer new and vital qualities into the future of our industry. This is entirely an ASM project and it rates all the support and all the interest exhibitors and visitors can give it.

SHOW LISTS "BLUE BOOK" OF AMERICAN METALS

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American Manganese Steel Div.
American Metal Market
American Metals Co., Ltd.
American Optical Co.
American Platinum Works
American Pullman Co., Inc.
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American Wheelabrator & Equipment Co.
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Commercial Steel Treating Corp.
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Nelson Stud Welding Division
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New Jersey Zinc Co.
Niagara Blower Co.
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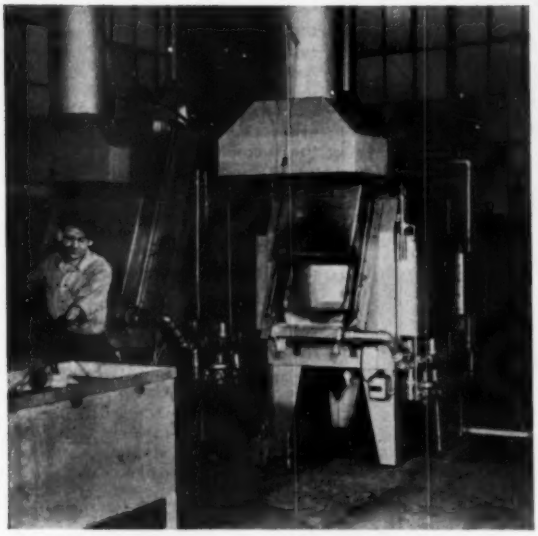

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Shown here is an electrically heated hydryzing furnace used for hardening high speed steel in controlled protective atmosphere. It operates at temperatures up to 2500° F. It has a CARBOFRAX silicon carbide hearth to resist the high temperatures and the abrasive action of the charge — also to prevent any spalling or cracking.

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We have a free booklet which outlines many specific applications. You'll find its recommendations may prove highly profitable.

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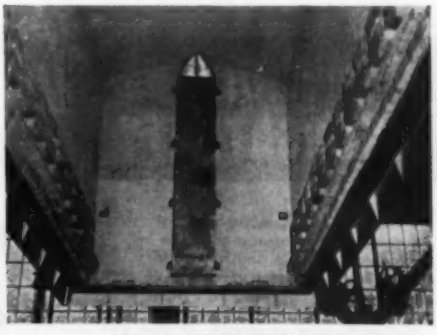
This furnace is used for bright annealing stainless steel in a hydrogen atmosphere. It is fired with gas, the burners being located underneath the hearth. CARBOFRAX tile are used to support the entire length of the alloy muffle because of their durability, high heat conductivity, and ability to withstand high temperatures without warping.



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Shown in its raised position is the cover of a cover type annealing furnace. It anneals coiled strip steel. CARBOFRAX baffles are used because of their high thermal conductivity, their ability to withstand high temperatures, and their unique resistance to heat shock.

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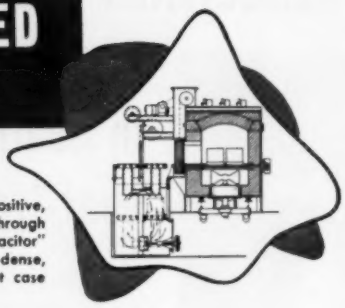

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Al-Cu-Ti Alloys

(Continued from p. 864)

the solution heat treated and naturally aged condition. It was also found that small additions of tin, of the order of 0.05%, exerted a marked effect on the tensile properties and aging characteristics of the commercial-purity aluminum–4½% copper alloy. In particular, the alloys containing tin showed considerably enhanced values of proof stress after artificial aging.

The behavior of tin in aluminum and aluminum-copper alloys suggested that other elements might be capable of producing similar results, and work was extended eventually to the Al – 4% Cu – 0.15% Ti alloy of very high purity containing elements adjacent to tin in the Periodic Table. Evidence for the solubility of these elements in aluminum has been obtained from the age hardening behavior of the binary alloys following solution heat treatment. The solid solubilities at 986° F. of cadmium, indium, and tin in aluminum are judged to be of the order of 0.05 to 0.1 weight per cent, whereas the solubilities of antimony, thallium, lead, and bismuth are taken to be negligibly small at this temperature.

Small quantities of the order of 0.05 weight per cent (0.012 atomic per cent), of cadmium, indium, or tin have a definite influence on the course of precipitation of copper in aluminum. The natural aging is depressed, but the rate of artificial aging is accelerated by a factor between three and eight. Both the response to artificial aging and the absolute strength are increased. The insoluble elements, antimony, thallium, lead, and bismuth, have no influence on the aging of the aluminum-copper alloy, although the bismuth particles mechanically reduce the strength properties.

Very small additions of magnesium, of the order of 0.06%, greatly diminish the influence of indium or tin, but do not affect the alloys containing cadmium. The quantity of magnesium required to neutralize the influence of indium or tin is approximately twice the ratio for the hypothetical compound Mg_2In or the stable compound Mg_2Sn.

Theoretical discussion of the results suggests that aggregates of "small" copper atoms are formed around the "large" atoms of the active elements during solution heat treatment. Such aggregates would

(Continued on p. 868)

Up "Popped" Production

...when Zonolite switched from ceramic to Inconel baffles

The Inconel baffles in this vermiculite ore-popping furnace save Zonolite $50 to $100 a day, as compared with ceramic baffles.

On the left are shown two Inconel baffles for comparison: one is after a year in use—the other is new. Fabricated by Brown-Hutchinson Iron Works, Detroit, Mich.

Expanding furnaces for "popping" vermiculite ore were causing the Zonolite Co., Dearborn, Mich., *expensive* trouble.

The ore passed through 1800°F. vertical furnaces where baffles slowed and distributed it evenly. But the baffles were made of ceramic and failed after a few months use.

Then Zonolite rebuilt two furnaces. In one, they used baffles made of ¼" Inconel plate. In the other, they used ceramic baffles.

Within nine months, the ceramic baffled furnace had to be rebuilt.

The Inconel baffled furnace continued to operate efficiently.

After eleven months, engineers tore down the Inconel furnace for inspection.

Here's what they found!

The Inconel baffle nearest the combustion zone was badly warped and needed to be replaced. The next two, slightly warped, could be straightened. The rest were in excellent shape.

The furnace was rebuilt and started again. It continued to operate efficiently for another year.

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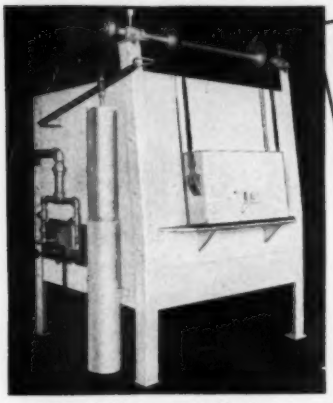

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WYCKOFF STEEL COMPANY

Al-Cu-Ti Alloys

(Continued from p. 866)

account for the lower rate of natural aging, if stable at room temperature. Accelerated aging at elevated temperature could be due to the aggregates acting as nuclei for the formation of so-called "Guinier-Preston zones" or zones of irregular distribution. Alternatively, the aggregates might be capable of rapid rearrangement to Guinier-Preston zones under the influence of thermal fluctuations. A completely different hypothesis of very rapid prior precipitation of the active elements on artificial aging to form nuclei for Guinier-Preston zones is less satisfactory, as it would not account for the reduced aging at room temperature.

The results have important practical implications, since they point the way to higher and controlled properties for commercial-purity aluminum-copper alloys. The variable response to heat treatment of the cast Al – 4½% Cu alloy, which is sometimes experienced, may well be due to the chance occurrence of small quantities of cadmium, indium, or tin.

Small quantities of cadmium, indium, or tin could be used to give enhanced proof-stress and maximum stress values in artificially aged aluminum-copper alloys. The slower rate of natural aging may also be of practical value in allowing fabricating processes to be carried out between solution heat treatment and artificial aging.

TOM BISHOP

Centrifugal Castings for Turbines*

USE of gas turbines in aircraft gave rise to production problems because many of the essential parts are necessarily made of metals which are not easy to machine, forge, or roll. In order to use cast components successfully, the castings must be produced entirely free from unsoundness and of such crystal structure that the inherent qualities of the material are developed to the fullest extent. Experience

(Continued on p. 870)

*Abstract of "Centrifugal Steel Castings for Gas Turbines", by J. Taylor and D. H. Armitage, Symposium on High Temperature Steels and Alloys for Gas Turbines, Iron and Steel Institute, February 1951, p. 205-208.

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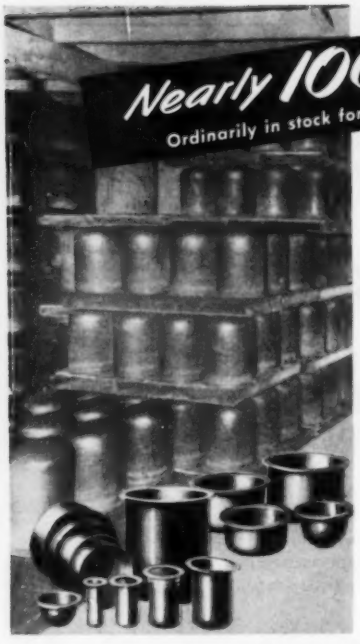

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Centrifugal Castings for Turbines

(Continued from p. 868)

had shown that centrifugally-cast bronze rims were greatly superior to orthodox bronze castings and it was on this experience that centrifugal casting of high quality steel parts was based. The best castings from a metallurgical standpoint are those plain ring-shaped parts centrifugally cast in steel molds where freezing always proceeds inward in a radial direction.

Because the gas turbine utilizes many parts that are essentially ring-shaped, it is more economical to produce the blanks for these parts by the horizontal or vertical axis method of centrifugal casting in metal molds. Parts of more complex shapes were centrifugally cast in sand molds. Difficulty was experienced at first in producing a mold which would neither erode nor be so hard as to cause hot tearing. These difficulties were overcome with the development of an oil-bonded silica sand that was used with a refractory wash.

To verify that the actual castings exhibited the optimum properties of the material, specimen castings were sawed through all critical sections for macro-examination and for tensile and impact testing. If even one characteristic fell below the specification requirements, the foundry method was altered and further tests were carried out until the castings were satisfactory.

These centrifugal castings are of two types:

(1) Castings operating at normal atmospheric temperature, but which are produced in high-tensile steel for weight reduction.

(2) Castings operating at high temperatures, up to 800° C. (1470° F.), where strength at elevated temperatures and resistance to scaling are of primary importance.

The high-tensile steels are of the low-alloy type containing generally up to 1½% Cr, 2% Ni, and about ½% Mo, with 0.3% C.

The castings, which operate at elevated temperatures, are produced in materials of rather widely differing compositions. The three types in most common use are *(a)* 18% Cr, 8% Ni, 1% Cb, *(b)* 25% Cr, 12% Ni, 3% W, and *(c)* 80% Ni, 15% Cr. The latter material finds use in those applications where a low co-efficient of expansion is essential.

C. K. Donoho

Technical Notes from Du Pont
on **MOLTEN SALT BATHS**

Some timely advantages of free-washing, accelerated salt baths

Although the standard cyanide bath is widely accepted for its dependability and ease of operation, certain features of free-washing accelerated salt baths are well worth noting today. Some of the timely advantages of a Du Pont Accelerated Salt WS Bath, *which is operated with a graphite cover*, are:

1. Cyanide savings—air oxidation of cyanide is substantially reduced.

2. Reduced power consumption—heat loss is cut, in some cases more than 50%.

3. Improved worker efficiency—better working conditions result from the retention of heat and fumes within the bath.

4. Increased flexibility—bath can be used for liquid carburizing as well as for cyaniding . . . reduces operating time and costs in many cases.

Besides these advantages over straight cyaniding, the water soluble accelerated salt bath is superior in a number of respects to barium chloride activated baths. For example, one valuable feature is that the work, whether oil- or water-quenched, washes completely free of salts —even when alkaline cleaners are used for removal of oil.

Another worth-while advantage is that you can virtually eliminate the "bail-out" usually required to maintain proper bath level and cyanide content in barium chloride activated baths. All you need do is select the proper replenishment salts from the wide range (96% Sodium Cyanide to 30% Cyanide-Chloride Mixture) which can be used with the Du Pont Accelerated Salt WS Bath.

The above technical information is offered in the interest of increased production through efficient operation and proper use of materials. In these critical times, Du Pont Technical Service stands ready to help you with your problems. For additional information and technical help without obligation, contact the Du Pont Electrochemicals Department district office nearest you. E. I. du Pont de Nemours & Co. (Inc.), Electrochemicals Dept., Wilmington, Delaware.

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Ceramic Coatings for Molybdenum*

THE high melting point (4750° F.) and comparatively large potential supply of molybdenum suggest that this metal may be useful at temperatures above the melting points of most metals and alloys. In order to use it at high temperatures in the presence of oxygen, however, the molybdenum must be protected against oxidation, and hence it is logical to apply a protective ceramic coating. Several such coatings were developed and applied in the form of water suspensions or "slips" to specimens of molybdenum, by dipping or spraying, after which the pieces were dried and fired at 2150° F. in oxygen-free atmospheres.

The approach chosen to obtain coatings having a combination of high refractoriness, impermeability, and adherence was to apply first a base coat having a high content of glassy phase, then a very refractory cover coat having little or no glassy phase, and finally to seal the pores of the cover coat with a top coat of the same characteristics as the base coat, each coating being separately fired.

Since the coefficient of thermal expansion of molybdenum is only about half that of ordinary low-carbon steel and about one third that of many high-temperature alloys, it was necessary to seek a frit composition having much lower expansion coefficient than the frits suitable for incorporating in coatings for the high-temperature alloys. Another characteristic required of the frit constituent of coatings for molybdenum is a much higher viscosity than was required for the frits previously developed for coatings of the heat resisting alloy type.

Tests of the coated pieces included *(a)* heating in a gas-oxygen flame, *(b)* heating at constant temperature in an air atmosphere, *(c)* thermal-shock tests, and *(d)* service testing of parts that were finished with a selected ceramic coating in the blast of ram-jet engines. The results of these various tests indicated that the oxidation of the

(Continued on p. 874)

*Abstract of "A Study of Ceramic Coatings for High-Temperature Protection of Molybdenum", by D. G. Moore, L. H. Bolz, and W. N. Harrison, Technical Note No. 1626, National Advisory Committee for Aeronautics.

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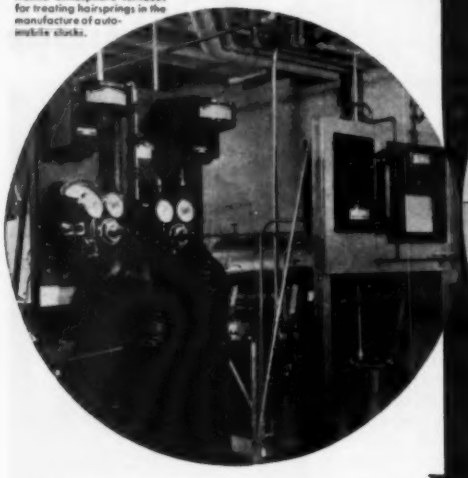

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Ceramic Coatings

(Continued from p. 872)

molybdenum was greatly retarded by the best of the ceramic coatings tried. In an air atmosphere at 1650° F., unprotected 0.040-in. molybdenum sheet was found to decrease to one half of its original thickness in ½ hr. There was no decrease for ceramic coated molybdenum heated for 70 hr. under the same conditions.

At a gas temperature approximating 3500° F., giving a surface temperature on the specimen of 2600° F. or more, only short-time protection of the molybdenum was attained. The oxidation rate at these high temperatures was found, however, to be sufficiently retarded by the presence of the ceramic coating to make the use of coated molybdenum feasible for special high-temperature applications in which prolonged service is not required.

One source of difficulty that can be expected in coating molybdenum is the gas absorbed in the metal. Appreciable quantities of gas may be present in relatively pure molybdenum sheet, and if gas is evolved when the metal is heated to high temperatures, it tends to cause blistering of the coating. In order to minimize serious disruption of the coating as a result of this blistering, the consistency of the ceramic coating during firing and use should permit sufficient flow to reseal the areas punctured by escaping gases. A preferable alternative, if attainable, would be to use metal that is substantially gas-free.

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(Continued on p. 876)

*Extracts from "Investment Casting of Nozzle Guide Vanes", by H. E. Gresham and A. Dunlop, a paper for the British Iron & Steel Institute's 1951 Symposium on High-Temperature Steels and Alloys for Gas Turbines.

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1. Move arrow to major class covering application
2. Select sub-group which best fits application
3. Note major tool characteristics (under arrow) and other characteristics in cut-outs for each grade in sub-group
4. Select tool steel indicated

That's all there is to it!

Here's an example:

Application—Deep drawing die for steel

Major Class—Metal Forming—Cold

Sub-Group—Special Purpose

Tool Characteristics—Wear Resistance

Tool Steel—Airdi 150

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FAIR LAWN, NEW JERSEY

Investment Casting

(Continued from p. 874)

deposit should remain. The wax should have low solidification shrinkage and have strength to withstand handling without distorting. The wax should also be insensitive to normal room-temperature variations. It must not be sticky. A material having admirable properties consists of 55% of resin, 30% of paraffin wax, 10% of candelilla wax, and 5% of carnauba wax. To facilitate removal of the wax pattern from its die, the latter may be thinly dressed with ethyl silicate.

Pattern Investment — To impart a smooth finish to the final mold cavity, a fine refractory coating is applied to the wax pattern assembly by spraying, dipping, or painting. A suitable spray-coat mixture is as follows:

Soap solution (1% soap flakes in water)	330 ml.
Sodium silicate	180 ml.
Dilute hydrochloric acid (10% by volume)	40 ml.
Flint powder (−200 mesh)	1120 g.

The soap solution acts as a wetting agent and aids suspension of the flint powder. The sodium silicate is a source of silicic acid binder when hydrolyzed by the hydrochloric acid.

The sprayed assembly is encased in a cylindrical metal container which is coated with wax and is fastened to the base plate by quick-acting clamps. A coarser grained refractory, mixed to a slurry with a liquid binder, is poured around the wax assembly, and the box is transferred to a vibrating table.

Because of the grain-size distribution of the refractory, it is possible to make a firm compact by vibrating the slurry. A suitable refractory is pulverized high-alumina firebrick of the following sieve analysis:

Sieve No.	% by Wt.	Sieve No.	% by Wt.
+16	1.5	−70, +80	3.6
−16, +30	29.5	−80, +90	1.4
−30, +40	12.3	−90, +100	2.0
−40, +50	7.5	−100, +150	6.3
−50, +60	3.9	−150, +200	4.3
−60, +70	3.8	−200	23.4

A good bonding liquid consists of a hydrolyzed solution of ethyl silicate. Because ethyl silicate is not miscible with water, a mutual solvent such as industrial methylated alcohol is used; 25 volumes of ethyl silicate, 69 volumes of methylated alcohol, 4.5 volumes of water, and 1.5 volumes of dilute hydrochloric acid (10% by volume) is satisfactory. From this liquid a film of col-

(Continued on p. 878)

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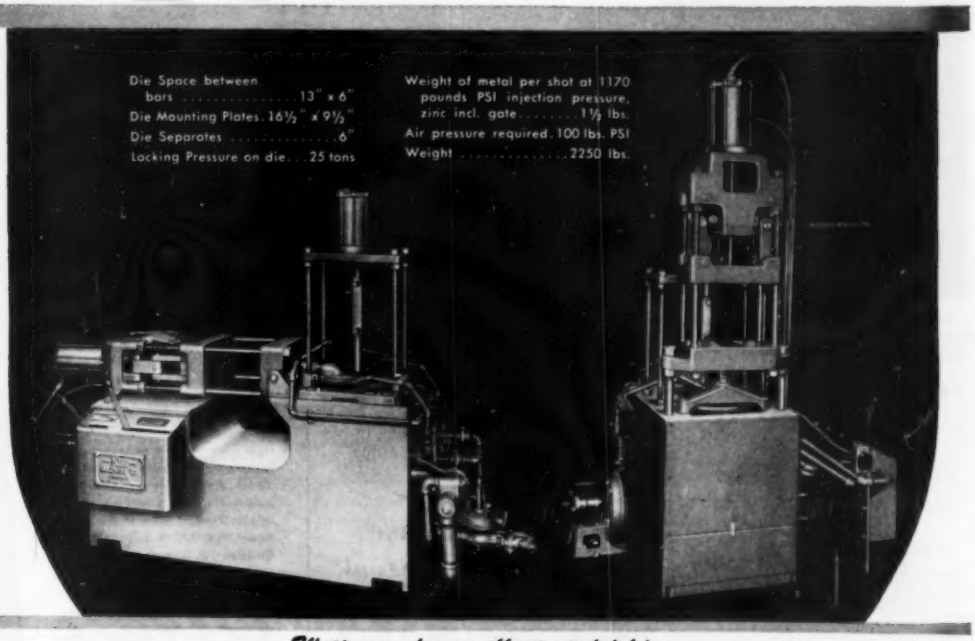
Die Space between bars . . . . . 13" x 6"
Die Mounting Plates. 16½" x 9½"
Die Separates . . . . . 6"
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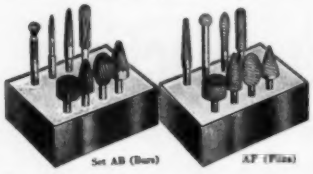

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Investment Casting

(Continued from p. 876)

loidal silica is deposited around the particles of sand, binding them together and producing a strong mass.

The hydrolysis can be represented by the equation:

$$Si(OC_2H_5)_4 + 2H_2O = SiO_2 + 4C_2H_5OH$$

Several factors govern the speed of reaction, including the temperature, the proportion of water, the electrolyte, and the catalyst, if used. In the above hydrolysis, hydrochloric acid is the electrolyte and a suitable catalyst is light calcined magnesia, added before mixing the slurry. After packing hard on the vibrating table the mold is allowed to stand for several hours for the hydrolysis to take place.

Wax is melted out for reuse by heating 8 hr. at 300° F., and the mold is put through a continuous furnace, the temperature reaching 1925° F. within 9 hr.

This firing serves three purposes:

1. The complete elimination of the volatile component of the binder.
2. The complete elimination of all traces of wax.
3. The raising of the mold to such a temperature that fine edges may be run successfully.

Precision — There are various factors affecting precision: The wax pattern shrinks on cooling and expands on melting out; the investment expands on heating; the molten alloy shrinks on cooling; the accuracy of the wax pattern can be affected by slight changes in composition, temperature and pressure of injection, and holding time in the die before ejection. Similarly, the accuracy of the mold can be affected by slight variations in composition and in heat treatment. Generally an accuracy of ±0.005 in. per in. is possible in the resulting casting.

Carbide Phase in Tempered Steel*

WITH the use of quenched austenite single crystals, Arbuzov and Kurdyumov in 1940 were able to detect by X-ray methods the presence of a carbide phase in steel

(Continued on p. 880)

*Abstract of "The Crystal Structure and Particle Size of the Carbide Phase in Tempered Steel", by M. P. Arbuzov, *Doklady Akademii Nauk SSSR*, Vol. 73, 1950, p. 83-86.

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Carbide Phase

(Continued from p. 878)

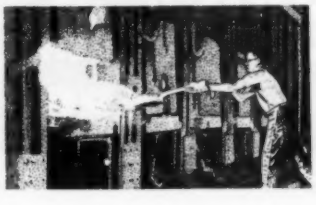
that was tempered in the range of 300 to 570° F. It was concluded from the diffraction pattern obtained that the carbide formed at 210 to 300° F. differed from Fe_3C, and it was called Fe_xC. Tempering at 570 to 750° F. caused the pattern of Fe_xC to disappear and to be replaced by that of Fe_3C.

The present work was designed to shed additional light on the change of Fe_3C. X-ray line widths were measured on carbide residues from 1% carbon steels tempered at 50° C. (122° F.) intervals from 100 to 700° C. (210 to 1290° F.). A 156-mm. camera was used. From photometric measurements of the line width it was possible to determine the size and shape of the carbide particles. Increasing line width was associated with lowering the tempering temperature, and crystal planes with a large third Miller index showed especially large widening. At tempering temperatures below 750° F., some lines broadened pronouncedly while others disappeared. Only about one third as many lines were in the pattern of the steel tempered at 390° F. as in that tempered at 1290° F. No lines appeared in the pattern of the steel tempered at 300° F.

At tempering temperatures below 750° F., the size of the carbide particle in the "Z" crystallographic direction was only about one third as great as in the other two directions. At higher temperatures this difference decreased as the particle grew larger. Even in those steels that were tempered at low temperatures, the carbide present had the lattice of Fe_3C.

It is stated that some of the reasons for the differences between the diffraction patterns of Fe_xC and Fe_3C are due to the plate form and the small dimensions of Fe_xC, especially in the "Z" direction. Part of the change that occurs on tempering at 570 to 750° F. is attributed to the result of changes in the interaction of the carbide and the solid solution.

A. G. GUY



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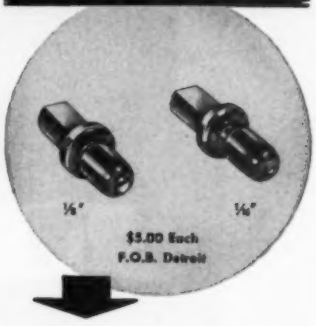

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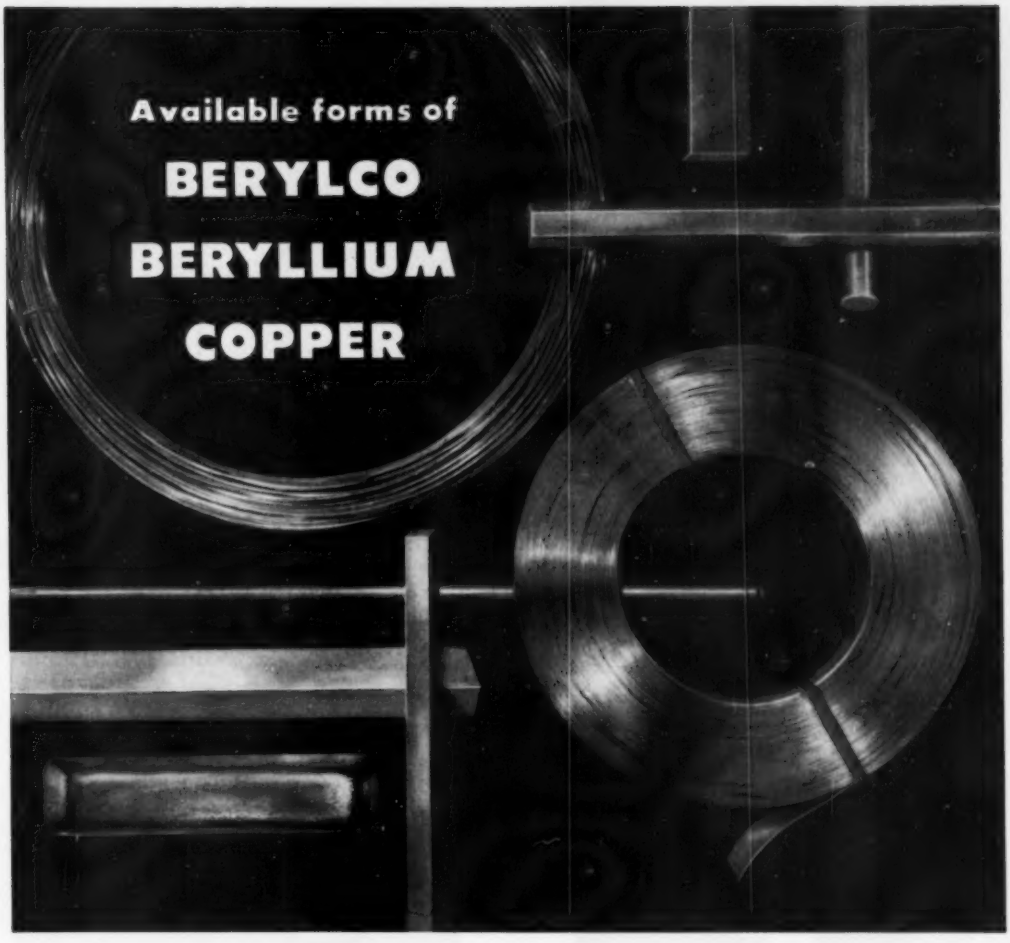

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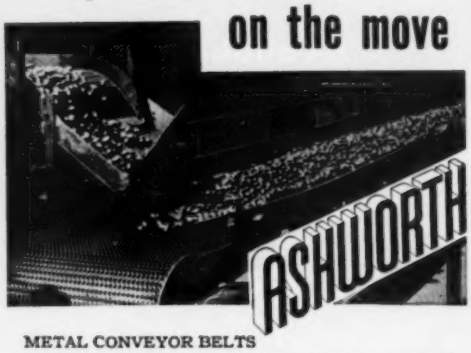

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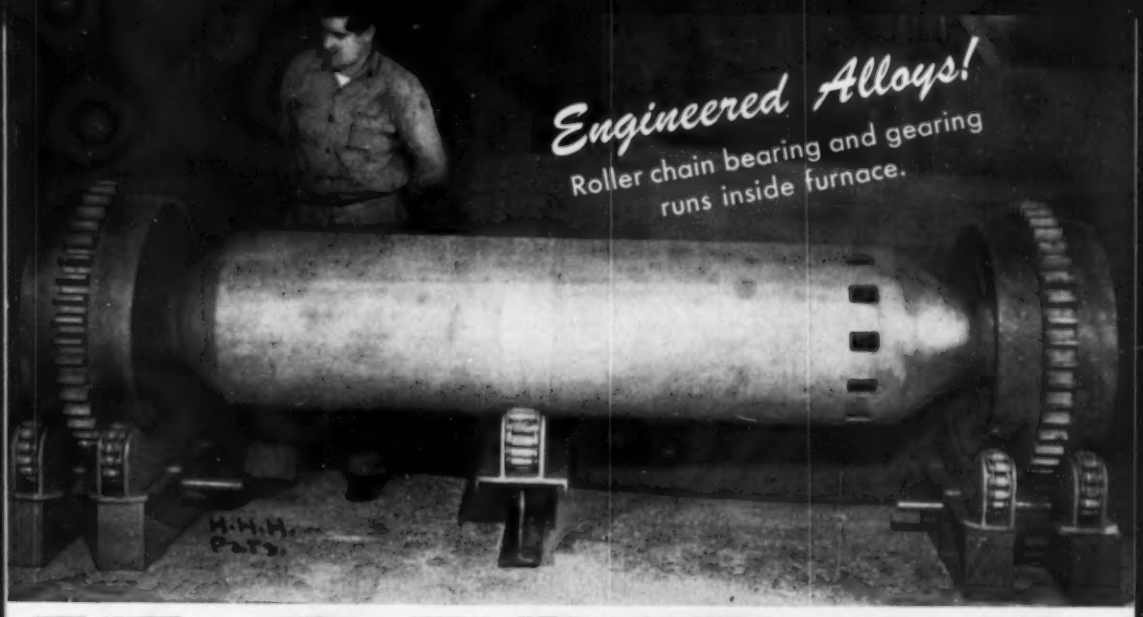

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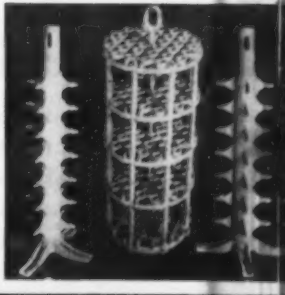

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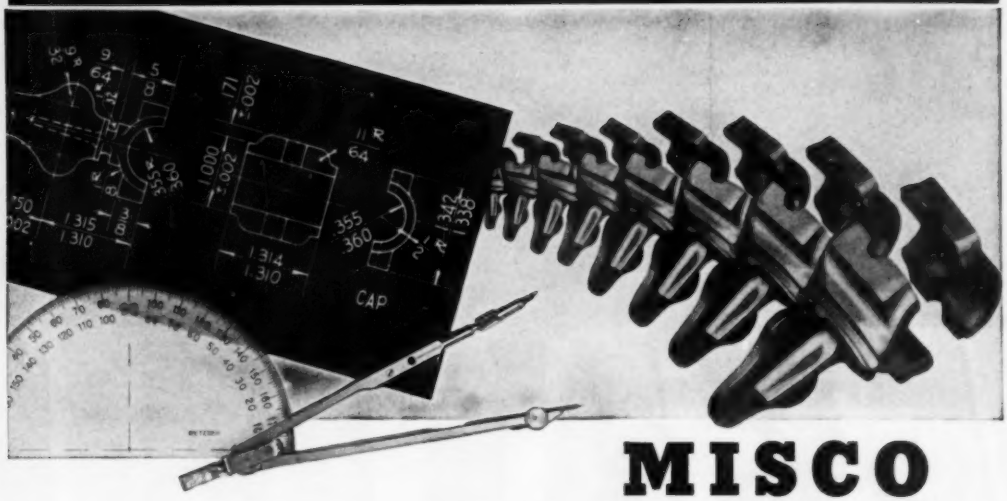

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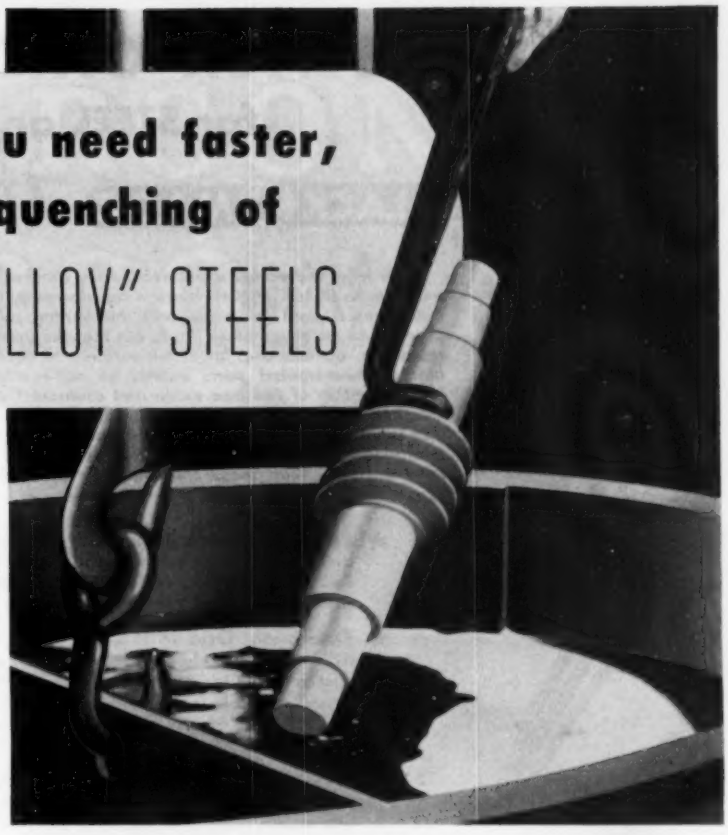

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Our long and varied experience in the blackening field with our well-known and proven BLACK MAGIC blackening processes, has brought out the fact that there was a need for a one-bath blackening solution which would not only produce an attractive black finish, but that the finish should have more corrosion resistance, operate at a lower temperature to decrease the dragout of solution, blacken heat-treated parts easily, be self-rectifying to inhibit the build-up in the solution of red iron oxide and counteract contaminants such as copper, zinc, etc., which frequently are introduced into the blackening solution; also, that the blackening solution in use should remain in chemical balance and new additions of salt be made by adding the required quantities of one chemically balanced salt. With these characteristics of a blackening bath in mind, the new BLACK MAGIC formula was developed.

★ **Easily blackens heat treated parts.** BLACK MAGIC Type A overcomes the difficulties normally present in applying a black oxide finish to cyanide hardened pieces, which have been oil quenched, and carbo-nitrided parts.

★ **One bath! One salt!** BLACK MAGIC Type A blackening process requires only 1 bath. The same salt mixture that makes up the initial solution is used to replenish dragout losses, thus maintaining at all times a true, chemically balanced BLACK MAGIC solution. Only 6½ lbs. of BLACK MAGIC salts are required to make up each gallon of solution.

★ **Lower operating temperature.** BLACK MAGIC Type A solution is operated at a boiling point of only 290° F. This substantially decreases the amount of dragout and effects important savings in heat consumption. The higher fluidity of the BLACK MAGIC solution lowers operating costs considerably.

★ **Self rectifying.** BLACK MAGIC Type A overcomes the normal tendency in black oxide processes to build up red iron oxide in colloidal form which eventually clings to the processed work. BLACK MAGIC is so formulated to be self rectifying and under normal and many abnormal conditions will keep the bath in excellent operating condition at all times.

★ **Faster blackening cycle.** Production baths of BLACK MAGIC Type A show a decrease in the blackening time cycles of from 15 to 20%. This is an important factor in speed up in production and lower cost of operation.

★ **More corrosion resistant.** BLACK MAGIC Type A has high absorption and adsorption qualities for oils and waxes normally used as a final finish dip. This characteristic gives infinitely higher corrosion resistant qualities to the finished parts.

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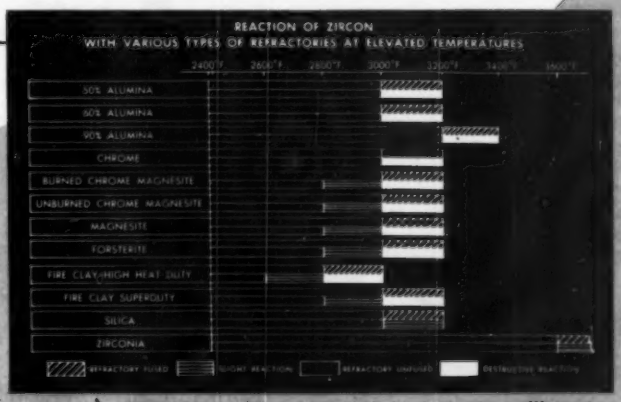

● Charted here is the reactivity in the temperature range from 2400°-3600°F

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The Nitriding Process; Factors Influencing Ammonia Consumption—A timely review of a process important in today's change-over production. This booklet discusses a two-stage process to reduce the gas consumption and eliminate the white layer.

The Carbonitriding Of Steel—Explaining the advantages, theory, atmospheres, equipment, operating conditions and industrial applications of this case-hardening process.

Effective Use Of Dissociated Ammonia—Describing the economy, advantages and various uses of dissociated ammonia in metal treating.

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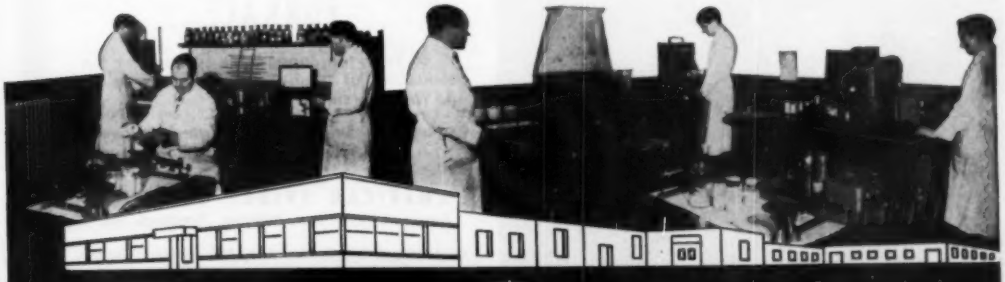
We have worked out a cleaning process for all metals in our laboratories that utilizes emulsion cleaners of the W/O type, based on petroleum products, to replace hot chlorinated solvent degreasing. In effect, this system is equivalent to spraying the work with solvent, while immersed in water, rather than in air. Since these emulsions are characteristically unstable, mechanical agitation is required to maintain dispersion of the solvent in the water phase. This agitation may be induced by propeller-type mixtures or by a pump-and-jet system. Both are effective and engineering details are available. The two-phase bath is built up of petroleum solvent procured at low cost by the user and treated with a small proportion of Northwest Addition Agent No. 230. The two-phase bath can also be prepared by adding, directly to the water, 5% to 20% Northwest Emulsion Cleaner No. 3. These baths may be heated to the maximum of 160° F., depending upon the solvent used. In some cases the agitation may be dispensed with, but in all cases the two-phase precleaning must be followed by a thorough spray rinse. This rinse has a unique cleaning effect in conjunction with a displacement film deposited on the metal in the emulsion precleaner. This film is extremely thin and invisible, but is essential to the complete removal of microscopic particles of foreign matter (smut) . . . Parts are carried on racks throughout the operation . . . the process is adaptable to the smallest shop or the largest plant, automatic or manual handling. *Let our technicians consult with you.*



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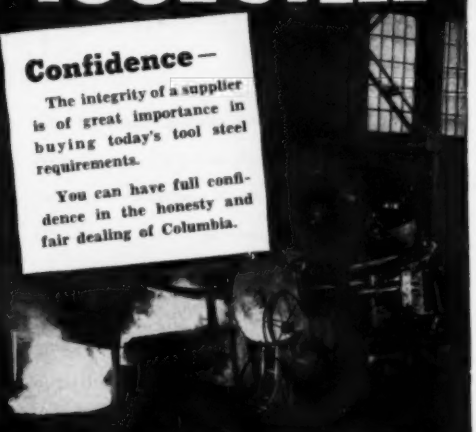

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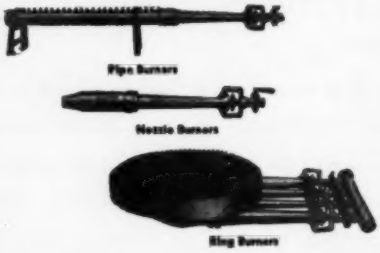

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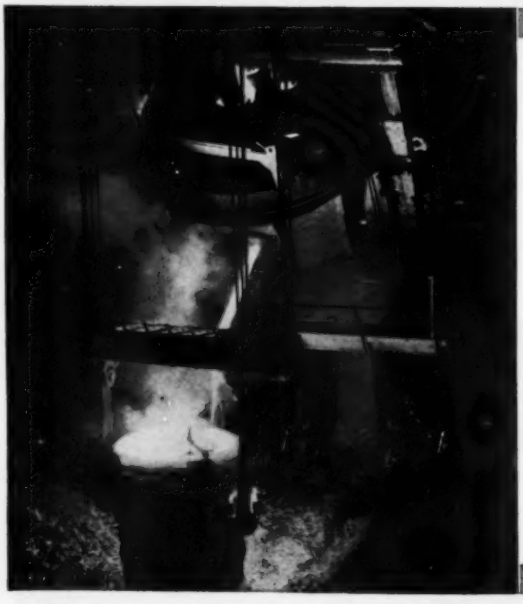

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Tests show New Quench Oil has Intensified Triple Action

● A new accelerated quenching oil has been developed that gives (1) rapid heat removal with faster cooling rate in the hardening range, this results in higher and deeper hardness; (2) slow cooling below the hardening range, thus minimizing distortion; (3) greater stability due to special anti-oxidants, for longer life and bright quenching properties.

To better illustrate the manner in which this triple action quenching oil accomplishes this higher quenching efficiency, it will be well to show the three stages of cooling as observed when steel is quenched in oil from a red heat. These stages are:

A. Formation of a vapor film at the steel surface; cooling is accomplished by conduction and radiation through this vapor film and is relatively slow.

B. Direct contact of the oil with the metal surfaces, causing a boiling action which continually dissipates the vapor film formed and results in rapid cooling.

C. After the metal has been cooled to the boiling point of oil, vapor is no longer formed; cooling is by conduction and convection, and the metal slowly cools to the temperature of the oil.

It is apparent that any improvement in the cooling power of oil in stages A and B would be most desirable. This can be compared to the brine quench which is used instead of water. Brine has a wetting action that completes the quench faster than fresh water, which "takes hold" only in spots, causing non-uniformity. Salt brine solutions provide deeper and more uniform hardnesses. This results in deeper and more even hardnesses. It seems logical to attempt to do this same thing with oil. The mineral intensifiers added to this Triple A Quenching Oil act in this manner.

Practical Application of Quench Curves to Hardening Steel

The improvement of oils so as to effect this desired change in the cooling characteristics has been attempted in the past by blending mineral oil with animal oils, but the product was prone to become rancid, or to decompose on contact with hot steel. These blends were also unsatisfactory as quenching mediums for steel treated in certain types of salt baths.

Developed in the Research Laboratory of the Park Chemical Co., the Park Triple A Quench Oil, a blend of specially refined mineral oils, cools steel faster in the upper temperature range by shortening the duration of vapor stage (A) and intensifying the action of boiling stage (B). Heat removal in stage (C) is slow and uniform. Thus, the best surface hardness and depth of hardness penetration are achieved with no danger of cracking or distortion.

Extremely stable, this new accelerated quenching oil may be used as a quench from any heat treating medium without fear of rancidity, oil breakdown, or change in quenching efficiency. Further, Park Triple A Oil is especially suitable for obtaining the maximum uniform oil-quenched hardenability from low and medium alloy steels.

Results of the improvement are shown in chart below showing actual hardnesses in quenched pieces. There is a 16% surface hardness increase with Park Triple A Oil over a good grade of straight mineral oil. The effect would be greater when comparing it with some of the poorer grades of oil used for quenching. Center hardnesses of the one-inch diameter piece are up 14%. Lighter sections would show even more increases.

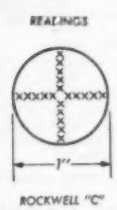
Bright Quenching and Stability

A very crucial and costly problem in the carbo-nitriding process has been the cleanliness of work after oil quenching. Oils which deteriorate rapidly or were originally unsuitable leave a sooty carbonaceous film on the surface of the work. This presents a difficult cleaning problem when followed by a plating or welding operation.

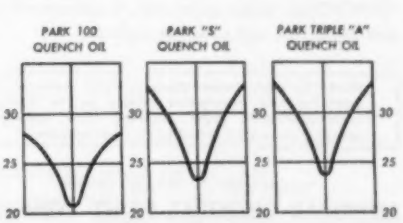
This difficulty, when not the fault of the furnace atmosphere, can be corrected by the use of Park Triple A Quench Oil.

Through the use of anti-oxidant additives and mineral intensifier it has been possible to prolong the bright quenching properties of good clean oil. Underwood Oxidation experiments have proven Park Triple A Quench Oil to have exceptional stability and long life.

A Bulletin, #F8, was prepared on Park's Triple A Quench Oil. It gives you a complete description of this oil with cooling curves, production data and photographs. Write Park Chemical Co., 8074 Military Ave., Detroit 4, Mich.



STEEL: S.A.E. 1045 1" ϕ x 2"
TREATMENT: 1550° F. IN NEUTRAL SALT QUENCH IN OIL AT 75° F.
HARDNESS: ROCKWELL "C" READINGS ACROSS INNER SURFACES OF SECTIONED SAMPLES



Transverse hardness Rc taken on 1" round SAE 1045 steel two inches long. Quench from Park's Nu-Sal neutral salt at 1550°F. into three types of quench oil, Park's No. 100 Oil (straight paraffin), Park's "S" Oil (compound with animal oil), Park's Triple A Oil. Oil temperatures 75° F.

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	U.S.A. 57-0-2, Type II, Class A U.S.A. 51-70-1, Finish 22.02, Class A	"THERMOIL-GRANODINE"
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ZINC	QQ-P-416 RR-C-82 JAN-F-495 AN-F-20 U.S.N. Appendix 6	"LITHOFORM"

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"THERMOIL-GRANODINE" forms a manganese-iron phosphate coating on steel, which, when oiled, provides wear-resistance for rubbing parts — and, when oiled or painted, inhibits corrosion.

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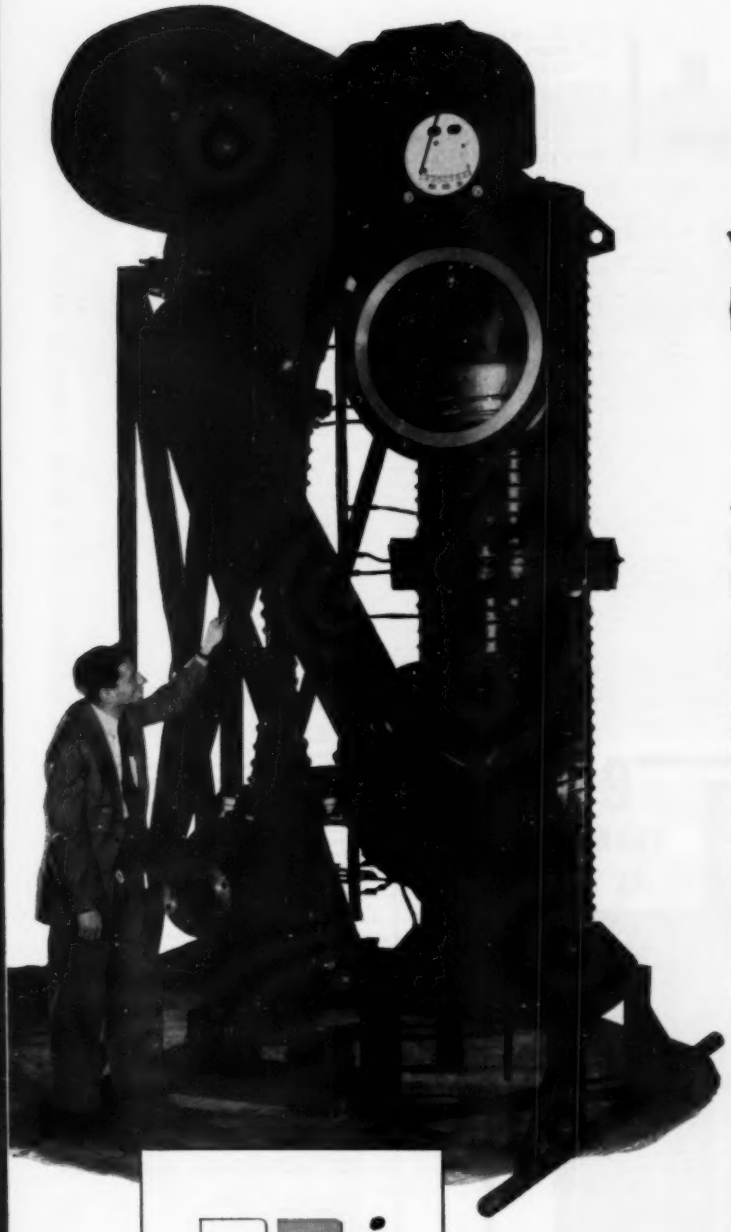

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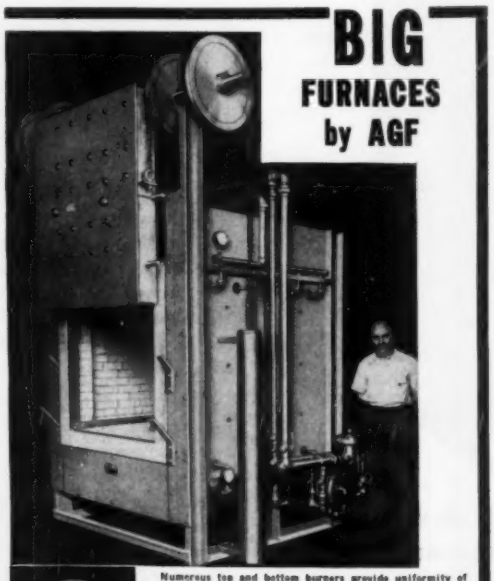

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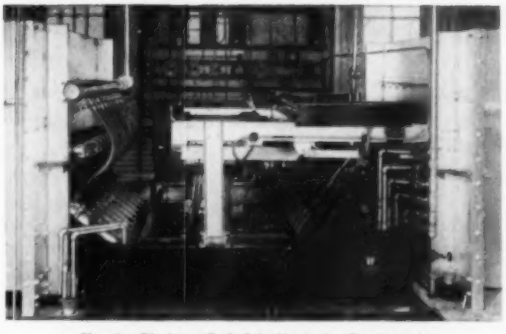

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